SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Dairy Wastes—Trebler and Harding

High-Rate Sludge Digestion—Sawyer and Roy

Public Bonding for Treatment Works—Ludwig et al.

Dual Aeration for Activated Sludge—Kraus

Digestion of Meat Packing Wastes—Steffen

Slime Formation—Heukelekian and Crosby

1955 Annual Index

DECEMBER, 1955—VOL. 27, No. 12

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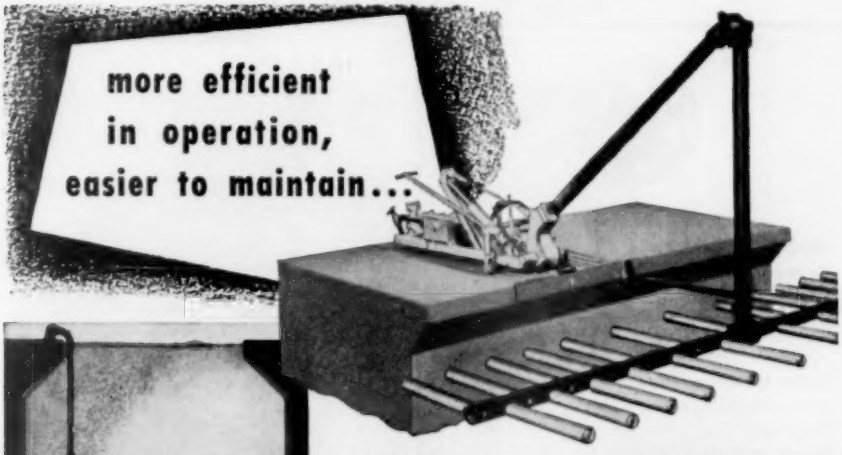

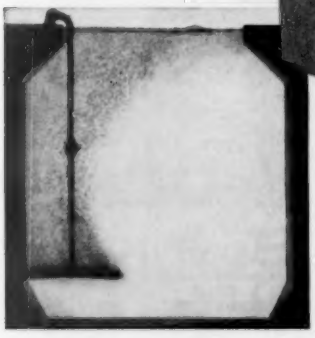

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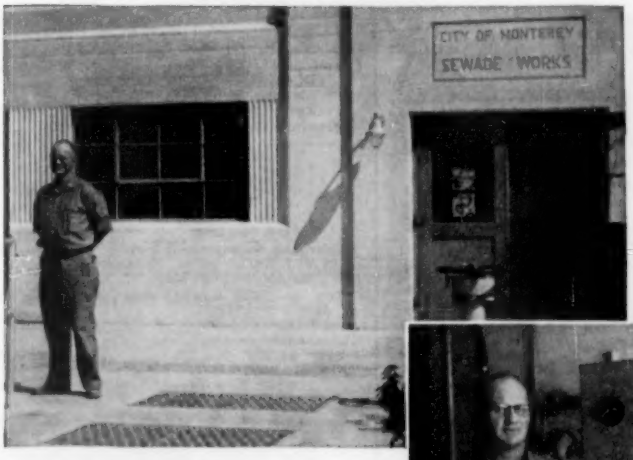

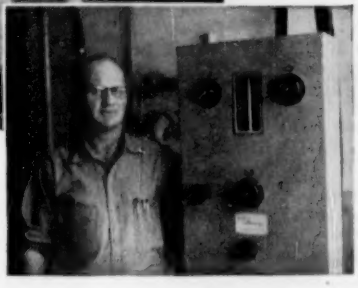

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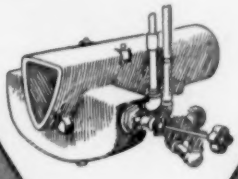

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Association	*Place*	*Time*
New York Sewage and Industrial Wastes Assn.	Belmont-Plaza New York City, N. Y.	Jan. 18–20, 1956
Texas Water and Sewage Assn.	Texas A & M College College Station, Tex.	Mar. 5–9, 1956
New Jersey Sewage and Industrial Wastes Assn.	Hotel Traymore Atlantic City, N. J.	Mar. 14–16, 1956
Arkansas Water and Sewage Conference (*Silver Anniversary*)	Marion Hotel Little Rock, Ark.	Mar. 19–21, 1956
Arizona Sewage and Industrial Wastes Assn.	Buena Vista Hotel Safford, Arizona	Apr. 5–7, 1956
Virginia Industrial Wastes and Sewage Works Assn.	Natural Bridge Hotel Natural Bridge, Va.	Apr. 19–20, 1956

TWENTY-NINTH ANNUAL MEETING

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in conjunction with

California Sewage and Industrial Wastes Association

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October 8–11, 1956

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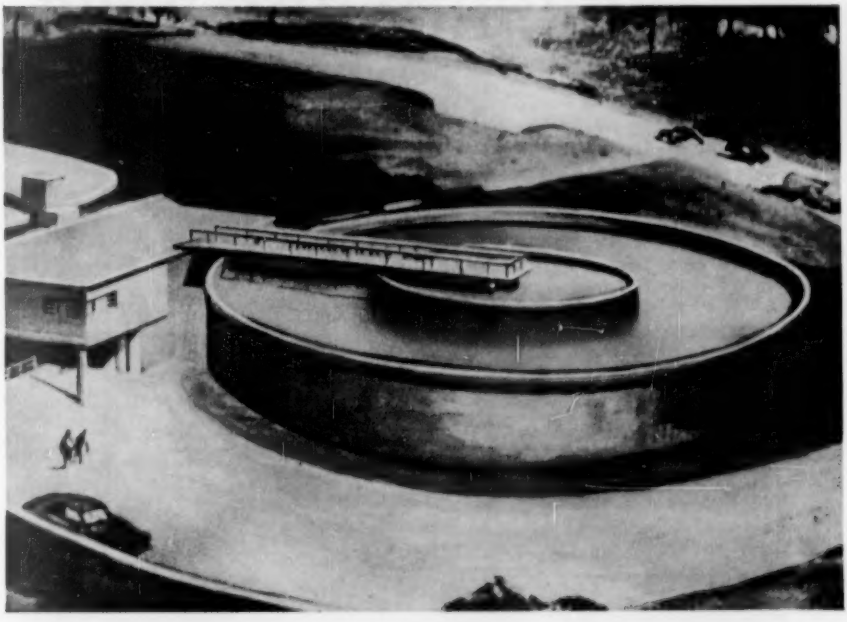

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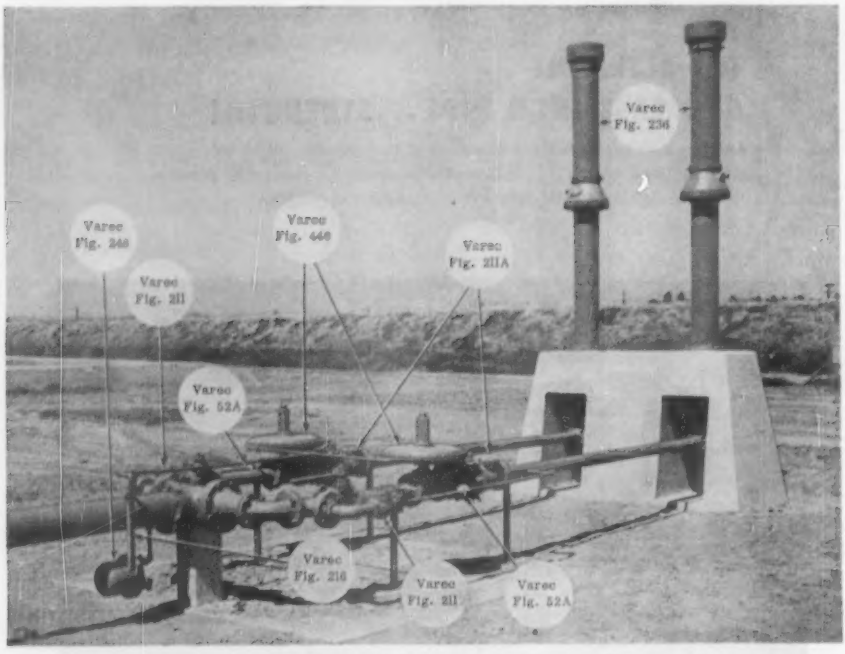

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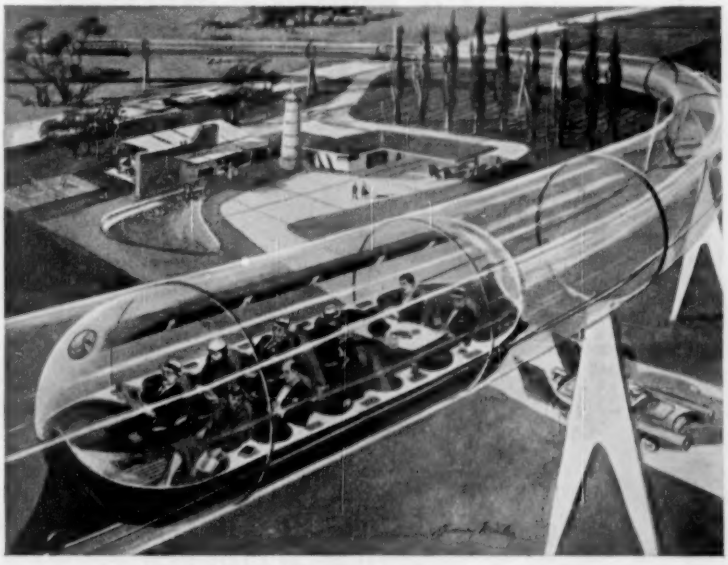

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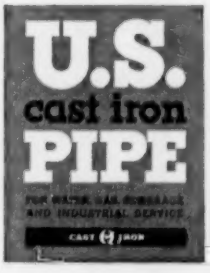

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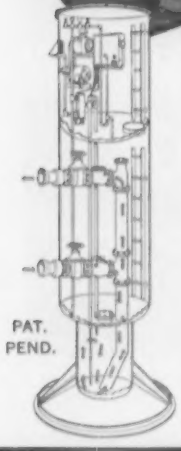

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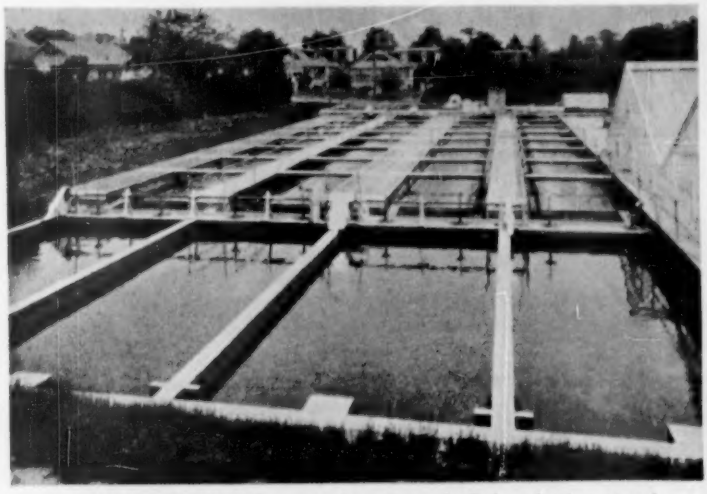

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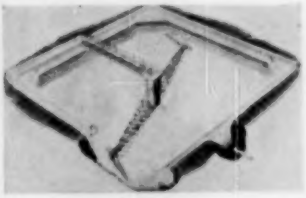

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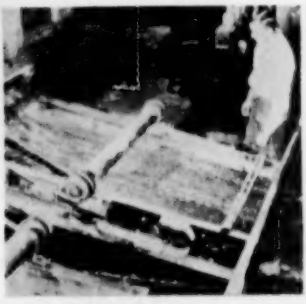

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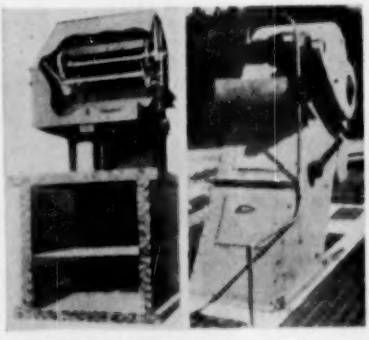

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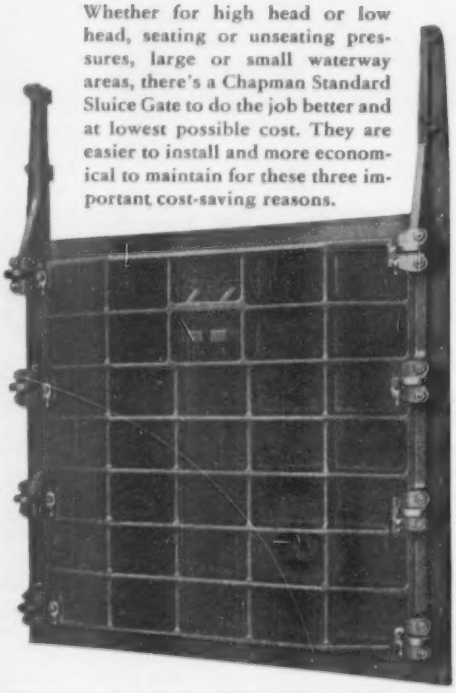

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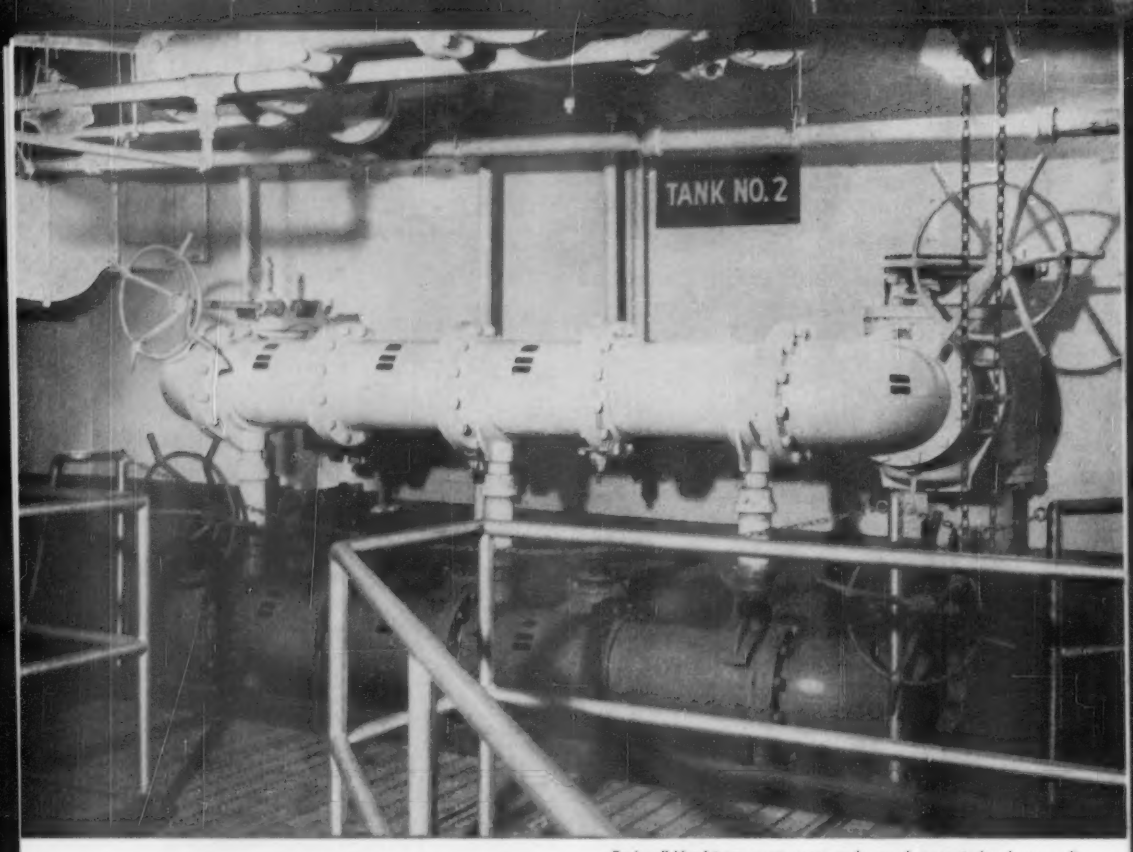

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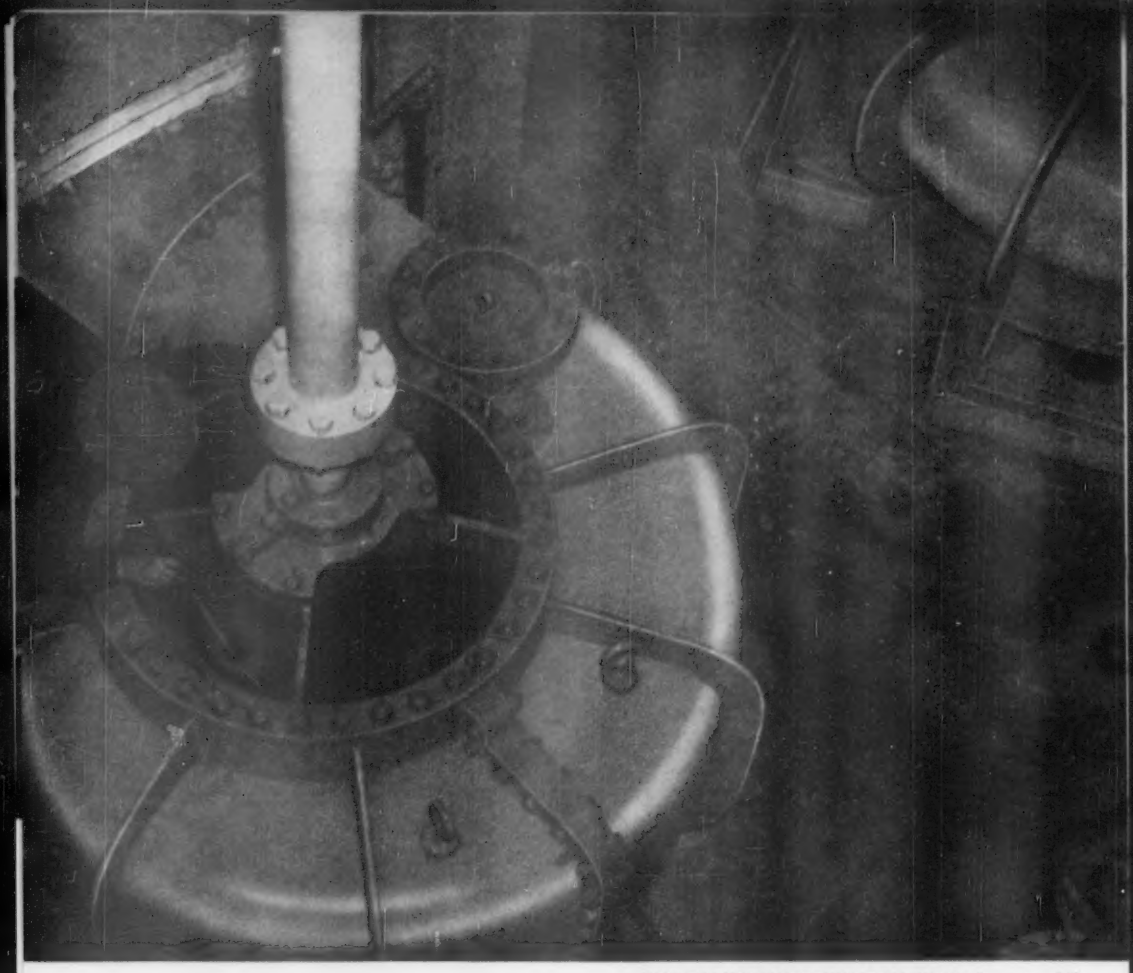

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 27 **December, 1955** **Number 12**

Contents

Sewage Works

Municipal Bonding for Sewage Treatment Facilities. By JOHN H. LUDWIG, B. J. STEIGERWALD, AND G. E. MCCALLUM 1335

Dual Aeration as a Rugged Activated Sludge Process. By L. S. KRAUS 1347

A Laboratory Evaluation of High-Rate Sludge Digestion. By C. N. SAWYER AND H. K. ROY 1356

Industrial Wastes

Full-Scale Modified Digestion of Meat Packing Wastes. By ALFRED J. STEFFEN .. 1364

Fundamentals of the Control and Treatment of Dairy Waste. By H. A. TREBLER AND H. G. HARDING 1369

Stream Pollution

Survival of Coliform Organisms in Pacific Ocean Coastal Waters. By ISADORE NUSBAUM AND RICHARD M. GARVER 1383

Slime Formation in Polluted Waters. I. Laboratory and Field Study Methods. By H. HEUKELEKIAN AND E. S. CROSBY 1391

A Constant Temperature Tank for Fish Bioassay Aquaria. By CHARLES M. WEISS 1399

The Operator's Corner

Small-Town Operator 1402

1955 Salary Survey of Iowa Sewage Works Personnel. By HARRIS F. SEIDEL 1403

A Double Duty Oxidation Pond. By EDWARD O. SAMPSON 1410

Interesting Extracts from Operation Reports: Racine, Wis.; Ley Creek, N. Y. 1415

Scale Model Sewage Treatment Plant 1420

Tips and Quips 1422

Reviews and Abstracts 1424

Book Reviews 1427

Author Index iii

Subject Index viii

Geographical Index xxii

Proceedings of Member Associations

Maryland-Delaware Water and Sewage Association 514a

Kentucky-Tennessee Industrial Wastes and Sewage Works Association 516a

Canadian Institute on Sewage and Sanitation 517a

South Dakota Water and Sewage Works Conference 518a

Equipment and Supply Lines 520a

RALPH E. FUHRMAN, *Editor*, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

DR. F. W. MOHLMAN, *Advisory Editor* DONALD P. SCHIESSWOHL, *Assistant Editor*

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Sewage Works

MUNICIPAL BONDING FOR SEWAGE TREATMENT FACILITIES

By John H. Ludwig, B. J. Steigerwald, and G. E. McCallum

Sanitary Engineers, Water Supply and Water Pollution Control Program, U. S. Public Health Service, Washington, D. C.

The Water Pollution Control Act, P. L. 845, is concerned with the control and abatement of water pollution due to municipal sewage and industrial wastes. To assist in the evaluation of obstacles to the construction of sewage treatment works by municipalities, the Water Supply and Water Pollution Control Program of the Public Health Service collected and analyzed data on financing of sewage treatment works selected from the *Bond Buyer* for the four-year period 1951–54. The results of this analysis are summarized in the tables that follow.

Selection of Sample

The sample used for the analysis consists of 341 bond issues representing expenditures of more than 420 million dollars, or roughly one-half the contract awards for sewage treatment works during this period. Bond data were taken from the monthly issues of the Municipal Bond Sales Section of the *Bond Buyer*. Projects were selected on the basis of availability of complete data, consisting of: the municipality or utility, type of facility, date, term, bond value, and basis or price. Since the description of the purpose of the bond, as listed in the *Bond Buyer*, is brief, it was difficult in some cases to separate bonds issued for sewage collection systems from those issued for interceptors or treatment works. Sewage collection system bonds were eliminated when the description definitely indicated them to be such; however, they were included for those cases of bond issues for combined collection systems and treatment facilities. It is difficult to state the exact portion of the sample represented by collection systems. It is estimated, however, that the dollar volume is not more than 10 per cent of the total included in the entire sample.

Analysis

Of the 341 bond issues totaling 421 million dollars, 184 issues totaling 264 million dollars are revenue bonds and 157 issues totaling 157 million dollars are general obligation bonds. The analysis of the data, as contained in Tables I through IX,* is summarized as follows:

1. Table I indicates a yearly breakdown of the data used in the sample into revenue bond issues and general obligation bond issues.

2. Tables II-A, II-B and II-C indicate by population groups the bond yield for the issues in each group. Bond yield, also referred to as the basis, represents the annual return on the bond taking into account premiums

* The "Adjusted Bond Yield Ratios" in these tables are the bond yields adjusted to reflect the fluctuating bond market by comparing the yield of each bond issue with the municipal bond index in the *Bond Buyer*.

or discounts. Mean and median bond yields for the issues in each group are shown. Mean bond yields were computed by weighting the yields for each issue by both term and principal, similar to the procedure used to determine the yield for a serial bond issue. Average terms, weighted by bond value, and total bond value in each group are also indicated. In addition, data entitled "Adjusted Bond Yield Ratios" are also shown. "Adjusted Bond Yield Ratios" are ratios of bond yields to the *Bond Buyer's* Index of Municipal Bond Average Yields. This index is determined by the *Bond Buyer* by averaging the market value of bonds expressed in "basis" of bonds (general obligation only) for 20 municipalities throughout the United States. Specific issues are not used in compiling these averages. Basis prices used are those applicable to a bond having a term of 20 years and generally selling at a price close to par. The index gives a general indication of the level of the municipal bond market. Adjusted bond yield data are included in the tables to allow consideration of fluctuations of the bond market when comparison is made of bond issues sold at different dates. Hence, these data are useful in giving an indication of mean, median and range in bond yields at a particular date by multiplying the *Bond Buyer's* index for that date by the ratios listed in the tables.

3. Tables III-A, III-B and III-C indicate, by bond value groups, the bond yield for the issues in each group. Mean and median bond yield and adjusted bond yield ratios for the issues in each group are shown. Average term, weighted by bond value, is also indicated.

4. Tables IV-A, IV-B and IV-C indicate, by geographical regions as delineated by standard census divisions, the bond yield for the series of issues in each region. Mean and median bond yield and adjusted bond yield ratios for the issues in each group are shown. Average term, weighted by bond value and total bond value in each region, is also shown.

5. Tables V-A, V-B, and V-C indicate, for quarter-percentage bond yield groups, the total bond value and percentage of the total in each group. Average term, weighted by bond value, is also indicated.

6. Tables VI-A, VI-B and VI-C indicate adjusted bond yield ratio groups, the total bond value and percentage of the total in each group. Average term, weighted by bond value, is also indicated. The adjusted bond yield ratio groups in Table VI correspond fairly well with the quarter-percentage bond yield groups listed in Table V.

7. Tables VII-A, VII-B and VII-C indicate the mean yield for bonds in the sample issued during each one-half-year period. For a general comparison the index from the *Bond Buyer* is listed for similar periods.

8. Table VIII indicates, for the single term issues in the sample, the variation of bond yield with term. Serial issues were not included in this analysis as the mean term for such issues is not significant. Individual issues in a serial issue were not included, since the entire issue is sold as a block and the price for individual issues sold separately would not necessarily be the same as the price for the entire issue. Mean and median bond yield and adjusted bond yield ratios for the issues in each group are shown.

9. Table IX indicates the breakdown, by population groups, of average annual contract awards for sewage treatment works for the period 1952–54.

Discussion

Since the selection of bond issues was made on the basis of availability of data as contained in the *Bond Buyer*, the sample analyzed is not a true cross section of construction for the period analyzed. A comparison of the "Per Cent of Total Bond Value" in the various population groups (column 4 of

Table II-A) with the "Per Cent of Total Construction Awards" (column 9 of Table IX) gives some indication of the disagreement between the sample and construction awards during 1952–54. This comparison shows that the sample is overweighted for population groups above 10,000. Also, a comparison of the annual bond value in the sample to the annual contract awards (column 9 of Table I) indicates that the sample is overweighted for 1954.

General information and points of interest in regard to municipal sewage treatment works financing as determined from the analysis include the following:

1. Tables II-A, II-B and II-C (Population groups):

a. Bond yields on the average are about one per cent less for large municipalities than for small ones. This applies to both revenue bonds and general obligation bonds.

b. In general, the range of bond yields for population groups as determined from the range of adjusted bond yield ratios, applied to the average index for the period, is more significant than the differences in bond yields between groups.

c. The bond yield for revenue bonds is generally a little over one-half per cent higher than for general obligation bonds.

d. The average term for revenue bonds is generally about five years greater than for general obligation bonds.

2. Tables III-A, III-B and III-C (Bond value groups):

a. Bond yields on the average are about one-half per cent less for large issues than for small ones.

b. In general, the range of bond yields for bond value groups as determined from the range of adjusted bond yield ratios applied to the average index for the period is more significant than the differences in bond yield between groups.

c. The average term is about 10 years greater for large issues than for small issues.

3. Tables IV-A, IV-B and IV-C (Geographical regions):

a. Bond yields are generally lower in the northeastern areas of the United States and generally higher in the southeastern area.

b. In general, the range of bond yields for the region as determined from the range of adjusted bond yield ratios applied to the average index for the period is generally more significant than the differences in yields between regions.

c. The average term is generally shorter in the same regions where bond yields are lower.

4. Tables V-A, V-B and V-C (Quarter-percentage yield groups):

a. For the sample analyzed, 50 per cent of the total bond value is financed with bond issues yielding less than the following: 2.8 per cent for the entire sample, 3.0 per cent for revenue bonds and 2.4 per cent for general obligation bonds.

b. The average term for the 50 per cent of the total bond value financed with the lower yielding bonds is about five years less than for the 50 per cent of construction volume financed with higher yielding bonds.

5. Tables VI-A, VI-B and VI-C: These tables present a comparison of bond yields in terms of the Index of Municipal Bond Average Yields, the *Bond Buyer*. This index reflects the general level of the municipal bond market.

a. For the total sample analyzed, the following percentages sold at yields below the index: 20 per cent for all bond issues, 9 per cent

for revenue bonds only, and 37 per cent for general obligation bonds only.

b. Fifty per cent of the total bond value is financed with bond issues with values of adjusted bond yield ratios less than the following: 1.18 for the entire sample, 1.24 for revenue bonds only, and 1.06 for general obligation bonds only. These values agree approximately with data obtained directly from Tables V using an index for the entire four-year period (arithmetic mean of monthly values) equal to 2.31. Exact comparison is not expected as the bond value of the sample is not distributed equally over the period.

c. For the total sample analyzed the following percentages of total bond value had yields greater than 150 per cent of the index: 6 per cent for all bond issues, 9 per cent for revenue bonds only, and 1 per cent for general obligation bonds only.

6. Tables VII-A, VII-B and VII-C: In general, bond issues for sewage treatment works construction have yields higher than the Index of Municipal Bond Average Yields of the *Bond Buyer*. The difference is greater during periods when the index is higher.

7. Tables VIII-A, VIII-B and VIII-C:

a. Long term bonds in general have yields about 1½ per cent higher than short term bonds.

b. The range of bond yields for individual term groups is more significant than the differences in yield between groups.

References

1. *Bond Buyer*, 67 Pearl St., New York 4, N. Y. (1951–54).
2. "Public Sewage Treatment Plant Construction." U. S. Pub. Health Service, Washington, D. C. (1952, 1953 and 1954).

TABLE I.—Summary of Data Used in Analysis[1]

Year	Revenue Issues		General Obligation Issues		Total Issues		Contract[2] Award ($, millions)	Per Cent of Contract Award in Sample (%)
	No.	Value ($, million)	No.	Value ($, million)	No.	Value ($, million)		
1951	37	34.0	40	44.4	77	78.4	177	44
1952	38	36.5	17	19.1	55	55.6	137	41
1953	34	44.4	19	47.5	53	91.9	191	48
1954	75	148.7	81	46.6	156	195.3	228	86
Total	184	263.6	157	157.6	341	421.2	733	58

[1] See reference 1.
[2] See reference 2.

TABLE II-A.—Bond Yield by Population Groups, Revenue and General Obligation Bonds

Population Group (Thousand)	No. of Issues	Bond Value			Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent of Total							
			In Group	Cumulative		Mean (%)	Median (%)	Mean	Median	Range
Under 1.0	17	1.4	0.3	0.3	13.7	3.70	3.39	1.54	1.50	1.00–2.10
1.0–2.5	37	6.4	1.5	1.8	17.6	3.47	3.19	1.50	1.40	0.84–2.10
2.5–5.0	41	10.1	2.4	4.2	14.9	2.86	2.65	1.26	1.20	0.75–1.95
5–10	62	26.9	6.4	10.6	17.7	3.09	2.87	1.30	1.75	0.73–1.58
10–25	72	70.8	16.8	27.4	18.1	3.02	2.65	1.31	1.20	0.67–2.10
25–50	37	42.3	10.0	37.4	18.4	3.22	2.48	1.24	1.10	0.66–1.67
50–100	22	66.5	15.8	53.2	17.8	2.60	2.43	1.11	1.05	0.73–1.53
100–250	29	121.2	28.8	82.0	22.3	3.24	2.69	1.27	1.20	0.69–1.57
250–500	15	53.8	12.8	94.8	19.1	2.78	2.05	1.25	0.90	0.69–1.61
500–1,000	4	8.9	2.1	96.9	12.6	1.75	1.84	0.95	0.90	0.71–1.06
Over 1,000	5	12.9	3.1	100.0	18.0	2.46	2.55	1.11	1.30	1.07–1.30
Total	341	421.2	100.0	100.0	19.2	3.00	2.69	1.25	1.17	0.66–2.10

TABLE II-B.—Bond Yield by Population Groups, Revenue Bonds Only

Population Group (Thousand)	No. of Issues	Bond Value			Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent of Total							
			In Group	Cumulative		Mean (%)	Median (%)	Mean	Median	Range
Under 1.0	3	0.3	0.1	0.1	18.6	4.84	4.50	2.05	2.06	1.92–2.10
1.0–2.5	18	3.8	1.4	1.5	20.0	3.79	3.58	1.66	1.50	1.27–2.10
2.5–5	19	5.3	2.0	3.5	16.8	3.19	2.98	1.38	1.30	1.00–1.95
5–10	39	19.9	7.5	11.0	19.4	3.21	2.99	1.35	1.40	0.91–1.41
10–25	47	53.2	20.2	31.2	19.8	3.18	3.07	1.39	1.30	0.87–1.17
25–50	21	30.8	11.7	32.9	20.3	3.39	2.66	1.29	1.20	0.87–1.67
50–100	10	30.8	11.7	44.6	21.9	2.83	2.73	1.20	1.10	0.80–1.53
100–250	18	66.2	25.2	69.8	19.8	2.86	2.83	1.18	1.20	0.90–1.35
250–500	7	45.6	17.3	87.1	19.8	2.86	2.54	1.29	1.10	0.86–1.61
500–1,000	—	—	—	—	—	—	—	—	—	— —
Over 1,000	3	7.7	2.9	100.0	16.4	2.49	2.55	1.13	1.09	1.07–1.26
Total	184	263.6	100.0	100.0	19.9	3.02	2.99	1.28	1.28	0.80–2.10

TABLE II-C.—Bond Yield by Population Groups, General Obligation Bonds Only

Population Group (Thousand)	No. of Issues	Bond Value			Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent of Total							
			In Group	Cumulative		Mean (%)	Median (%)	Mean	Median	Range
Under 1.0	14	1.1	0.7	0.7	12.5	3.28	3.24	1.35	1.40	1.00–1.82
1.0–2.5	19	2.6	1.7	2.4	14.1	2.83	2.85	1.17	1.20	0.84–1.58
2.5–5	23	4.8	3.1	5.5	12.7	2.39	2.33	1.08	1.10	0.75–1.51
5–10	23	7.0	4.4	9.9	13.0	2.55	2.41	1.07	1.10	0.73–1.58
10–25	25	17.6	11.1	21.0	12.7	2.27	2.12	0.95	0.90	0.67–2.10
25–50	16	11.5	7.3	28.3	13.1	2.50	2.26	1.05	1.00	0.66–1.52
50–100	12	35.7	22.6	50.9	14.2	2.30	2.19	0.99	0.95	0.73–1.31
100–250	11	55.0	35.0	85.9	25.4	3.59[1]	2.17	1.36	1.10	0.69–1.57
250–500	8	8.2	5.2	91.1	15.0	2.21	1.91	0.94	0.80	0.69–1.06
500–1,000	4	8.9	5.6	96.7	12.6	1.75	1.84	0.95	0.90	0.71–1.06
Over 1,000	2	5.2	3.3	100.0	20.6	2.41	2.80	1.09	1.19	1.09–1.30
Total	157	157.6	100.0	100.0	17.9	2.95	2.34	1.18	1.03	0.66–2.10

[1] This value includes a bond issue by the city of Miami, Fla., for $27,100,000 with a bond yield of 4.322 per cent. By omitting this issue from the group the mean bond yield for the group becomes 2.49 per cent with an average term of 19.9 years, and for the entire sample 2.36 per cent with an average term of 15.3 years.

TABLE III-A.—Bond Yield by Bond Value Groups, Revenue and General Obligation Bonds

Bond Value Groups ($, thousand)	No. of Issues	Bond Value			Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent of Total							
			In Group	Cumulative		Mean (%)	Median (%)	Mean	Median	Range
Under 25	14	0.2	0.1	0.1	10.6	3.20	3.01	1.60	1.30	0.79–2.10
25–49	11	0.4	0.1	0.2	8.3	3.04	2.76	1.42	1.38	0.91–2.06
50–99	20	1.4	0.3	0.5	10.8	3.19	2.64	1.38	1.19	0.69–1.95
100–249	62	10.5	2.5	3.0	13.5	2.94	2.71	1.29	1.21	0.67–2.10
250–499	73	24.3	5.8	8.8	15.6	2.92	2.65	1.27	1.15	0.69–1.88
500–999	55	37.2	8.8	17.6	15.6	2.98	2.79	1.30	1.22	0.66–1.90
1,000–2,499	60	93.6	22.2	39.8	17.2	2.82	2.52	1.23	1.17	0.71–1.58
2,500–4,999	25	82.0	19.5	59.3	17.6	2.81	2.64	1.14	1.06	0.73–1.67
5,000–9,999	18	112.5	26.7	86.0	20.9	2.71	2.61	1.17	1.13	0.89–1.39
10,000 or over	3	59.1	14.0	100.0	26.2	3.82	3.26	1.45	1.44	1.33–1.49
Total	341	421.2	100.0	100.0	19.2	3.00	2.69	1.25	1.17	0.66–2.10

TABLE III-B.—Bond Yield by Bond Value Groups, Revenue Bonds Only

Bond Value Groups ($, thousand)	No. of Issues	Bond Value			Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent of Total							
			In Group	Cumulative		Mean (%)	Median (%)	Mean	Median	Range
Under 25	3	0.04	0.1	0.1	7.8	3.74	3.75	1.90	1.72	1.50–2.08
25–49	4	0.1	0.1	0.2	6.5	3.59	3.50	1.52	1.39	0.91–2.06
50–99	9	0.6	0.2	0.4	13.6	3.72	3.48	1.61	1.45	1.14–1.95
100–249	22	3.7	1.4	1.8	16.1	3.32	3.08	1.50	1.36	0.87–2.10
250–499	41	14.2	5.4	7.2	17.8	3.18	2.88	1.36	1.27	0.87–1.88
500–999	33	22.8	8.6	15.8	18.6	3.33	3.18	1.44	1.34	1.04–1.90
1,000–2,499	42	66.4	25.1	40.9	18.4	3.00	2.86	1.30	1.25	0.80–1.58
2,500–4,999	17	55.2	21.0	61.9	19.0	2.99	2.72	1.20	1.10	0.86–1.67
5,000–9,999	11	68.6	26.0	87.9	22.2	2.84	2.83	1.19	1.14	1.04–1.39
10,000 or over	2	32.0	12.1	100.0	22.2	3.22	3.18	1.41	1.39	1.33–1.44
Total	184	263.6	100.0	100.0	19.9	3.02	2.99	1.28	1.33	0.80–2.10

TABLE III-C.—Bond Yield by Bond Value Groups, General Obligation Bonds Only

Bond Value Groups ($, thousand)	No. of Issues	Bond Value			Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent in Total							
			In Group	Cumulative		Mean (%)	Median (%)	Mean	Median	Range
Under 25	11	0.2	0.1	0.1	11.3	3.12	2.85	1.55	1.15	0.79–2.10
25–49	7	0.2	0.1	0.2	9.4	2.82	2.50	1.38	1.18	1.00–1.82
50–99	11	0.8	0.5	0.7	8.5	2.49	1.97	1.09	1.06	0.69–1.45
100–249	40	6.8	4.2	4.9	12.1	2.66	2.54	1.14	1.09	0.67–1.58
250–499	32	10.0	6.4	11.3	12.7	2.45	2.29	1.08	1.01	0.69–1.58
500–999	22	14.5	9.2	20.5	10.9	2.08	2.01	0.92	0.93	0.66–1.31
1,000–2,499	18	27.1	17.2	37.7	14.2	2.24	2.16	1.00	0.95	0.71–1.19
2,500–4,999	8	26.9	17.1	54.8	14.8	2.31	2.30	0.97	0.97	0.73–1.15
5,000–9,999	7	44.0	28.0	82.8	18.6	2.46	2.39	1.13	1.09	0.89–1.31
10,000 or over	1	27.1	17.2	100.0	31.1	4.32	4.32	1.49	1.49	—
Total	157	157.6	100.0	100.0	17.9	2.95	2.34	1.18	1.03	0.66–2.10

TABLE IV-A.—Bond Yield by Geographical Regions, Revenue and General Obligation Bonds

Regional Areas[1]	No. of Issues	Bond Value		Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent in Group		Mean (%)	Median (%)	Mean	Median	Range
New England	5	4.7	1.1	13.1	1.81	1.73	0.92	0.80	0.69–1.13
Middle Atlantic	39	74.9	17.8	19.9	2.99	2.39	1.28	1.07	0.67–1.64
East North Central	115	123.7	29.2	17.4	2.63	2.71	1.14	1.15	0.66–2.10
West North Central	30	13.9	3.3	12.8	2.56	2.52	1.08	1.04	0.73–1.50
South Atlantic	47	86.9	20.6	23.4	3.58	2.82	1.38	1.30	0.82–1.67
East South Central	30	50.0	11.9	21.0	3.07	3.04	1.24	1.31	1.08–2.10
West South Central	36	43.1	10.4	14.7	2.61	2.93	1.17	1.28	0.86–2.08
Mountain	7	9.8	2.3	26.2	2.91	2.93	1.27	1.27	1.06–1.41
Pacific	32	14.2	3.4	15.7	2.72	2.69	1.22	1.22	0.71–1.92
Total	341	421.2	100.0	19.2	3.00	2.69	1.25	1.17	0.66–2.10

[1] Standard census division.

TABLE IV-B.—Bond Yield by Geographical Regions, Revenue Bonds Only

Regional Areas[1]	No. of Issues	Bond Value		Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent in Group		Mean (%)	Median (%)	Mean	Median	Range
New England	—	—	—	—	—	—	—	—	—
Middle Atlantic	12	43.8	16.6	22.2	3.16	3.06	1.35	1.37	0.89–1.64
East North Central	58	71.4	27.1	20.2	2.91	3.09	1.24	1.35	0.91–2.08
West North Central	8	6.8	2.6	15.7	2.70	2.71	1.14	1.16	0.80–1.50
South Atlantic	30	44.9	17.0	21.5	3.23	3.03	1.36	1.33	0.95–1.67
East South Central	30	50.0	19.0	21.0	3.07	3.04	1.24	1.31	1.08–2.10
West South Central	27	37.0	14.0	14.4	2.63	3.07	1.17	1.35	0.86–2.08
Mountain	4	1.7	0.6	16.6	3.79	3.06	1.51	1.32	1.17–1.41
Pacific	15	8.0	3.1	18.4	2.99	2.88	1.30	1.22	0.87–1.92
Total	184	263.6	100.0	19.9	3.02	2.99	1.28	1.33	0.80–2.10

[1] Standard census division.

TABLE IV-C.—Bond Yield by Geographical Regions, General Obligation Bonds Only

Regional Areas[1]	No. of Issues	Bond Value		Av. Term (Yr.)	Actual Bond Yield		Adjusted Bond Yield Ratios		
		$ (million)	Per Cent in Group		Mean (%)	Median (%)	Mean	Median	Range
New England	5	4.7	3.0	13.1	1.81	1.73	0.92	0.80	0.69–1.13
Middle Atlantic	27	31.1	19.7	16.6	2.67	2.34	1.15	1.03	0.67–1.31
East North Central	57	52.3	33.1	13.4	2.06	2.27	0.94	0.96	0.66–2.10
West North Central	22	7.1	4.5	10.0	2.36	2.42	0.99	1.03	0.73–1.49
South Atlantic	17	42.0	26.7	25.5	3.89	2.37	1.39	1.09	0.82–1.58
East South Central	—	—	—	—	—	—	—	—	—
West South Central	9	6.1	3.9	16.2	2.55	2.53	1.14	1.18	0.93–1.62
Mountain	3	8.1	5.1	28.2	2.80	2.43	1.24	1.18	1.06–1.28
Pacific	17	6.2	4.0	12.2	2.21	2.34	1.06	1.15	0.71–1.61
Total	157	157.6	100.0	17.9	2.95	2.34	1.18	1.03	0.66–2.10

[1] Standard census division.

TABLE V-A.—Distribution by Bond Yield, Revenue and General Obligation Bonds

Bond Yield Group (%)	No. of Issues	Bond Value			Av. Term (Yr.)
		$ (million)	Per Cent of Total		
			In Group	Cumulative	
1.25–1.49	6	11.6	2.7	2.7	14.6
1.50–1.74	21	25.6	6.1	8.8	15.5
1.75–1.99	22	28.2	6.7	15.5	12.9
2.00–2.24	37	29.3	6.9	22.4	13.4
2.25–2.49	51	51.2	12.2	34.6	15.4
2.50–2.74	46	60.1	14.2	48.8	19.4
2.75–2.99	41	49.7	11.7	60.5	20.1
3.00–3.24	34	40.3	9.6	70.1	21.9
3.25–3.49	36	55.1	13.1	83.2	21.5
3.50–3.74	19	15.8	3.7	86.9	21.0
3.75–3.99	12	20.6	4.9	91.8	19.9
4.00–4.24	9	3.3	0.8	92.6	25.1
4.25–4.49	2	27.5	6.5	99.1	31.0
4.50–4.74	4	2.7	0.6	99.7	22.5
4.75–4.99	—	—	—	—	—
5.00–5.24	1	0.2	0.3	100.0	22.5
Total	341	421.2	100.0	100.0	19.2

TABLE V-B.—Distribution by Bond Yield, Revenue Bonds Only

Bond Yield Group (%)	No. of Issues	Bond Value			Av. Term (Yr.)
		$ (million)	Per Cent of Total		
			In Group	Cumulative	
1.25–1.49	—	—	—	—	—
1.50–1.74	2	11.5	4.3	4.3	19.2
1.75–1.99	6	12.7	4.8	9.1	12.5
2.00–2.24	9	10.4	3.9	13.0	15.4
2.25–2.49	19	17.0	6.4	19.4	14.9
2.50–2.74	25	44.0	16.8	36.2	20.2
2.75–2.99	32	39.9	15.1	51.3	18.6
3.00–3.24	25	38.4	14.6	65.9	22.3
3.25–3.49	27	54.1	20.5	86.4	21.6
3.50–3.74	13	15.0	5.7	92.1	21.2
3.75–3.99	11	14.0	5.3	97.4	23.0
4.00–4.24	9	3.3	1.3	98.7	25.1
4.25–4.49	1	0.4	0.2	98.9	24.5
4.50–4.74	4	2.7	1.0	99.9	22.5
4.75–4.99	—	—	—	—	—
5.00–5.24	1	0.2	0.1	100.0	22.5
Total	184	263.6	100.0	100.0	19.9

TABLE V-C.—Distribution by Bond Yield, General Obligation Bonds Only

Bond Yield Group (%)	No. of Issues	Bond Value			Av. Term (Yr.)
		$ (million)	Per Cent of Total		
			In Group	Cumulative	
1.25–1.49	6	11.6	7.3	7.3	14.6
1.50–1.74	19	14.1	8.9	16.2	12.5
1.75–1.99	16	15.5	9.8	26.0	13.1
2.00–2.24	28	18.9	12.0	38.0	12.2
2.25–2.49	32	34.2	21.6	59.6	15.6
2.50–2.74	21	16.1	10.5	70.1	17.1
2.75–2.99	9	9.8	6.2	76.3	25.6
3.00–3.24	9	1.9	1.2	77.5	13.6
3.25–3.49	9	1.0	0.6	78.1	15.2
3.50–3.74	6	0.8	0.5	78.6	16.0
3.75–3.99	1	6.6	4.2	82.8	13.3
4.00–4.24	—	—	—	—	—
4.25–4.49	1	27.1	17.2	100.0	31.1
4.50–4.74	—	—	—	—	—
4.75–4.99	—	—	—	—	—
5.00–5.24	—	—	—	—	—
Total	157	157.6	100.0	100.0	17.9

TABLE VI-B.—Distribution by Adjusted Bond Yield Ratios, Revenue Bonds Only

Adjusted Bond Yield Ratio Group (%)	No. of Issues	Bond Value			Av. Term (Yr.)
		$ (million)	Per Cent of Total		
			In Group	Cumulative	
0.60–0.69	—	—	—	—	—
0.70–0.79	—	—	—	—	—
0.80–0.89	6	10.5	4.0	4.0	15.9
0.90–0.99	8	12.8	4.9	8.9	12.0
1.00–1.09	18	36.1	13.7	22.6	17.1
1.10–1.19	28	59.8	22.7	45.3	20.6
1.20–1.29	29	32.0	12.1	57.4	19.2
1.30–1.39	36	48.6	18.4	75.8	22.0
1.40–1.49	22	39.7	15.1	90.9	22.5
1.50–1.59	15	14.6	5.5	96.4	21.8
1.60–1.69	9	7.0	2.7	99.1	20.0
1.70–1.79	3	0.3	0.1	99.2	18.7
1.80–1.89	2	0.8	0.3	99.5	26.4
1.90–1.99	3	0.9	0.3	99.8	16.3
2.00–2.09	4	0.3	0.1	99.9	13.6
2.10–2.19	1	0.2	0.1	100.0	22.5
Total	184	263.6	100.0	100.0	19.9

TABLE VI-A.—Distribution by Adjusted Bond Yield Ratios, Revenue and General Obligation Bonds

Adjusted Bond Yield Ratio Group (%)	No. of Issues	Bond Value			Av. Term (Yr.)
		$ (million)	Per Cent of Total		
			In Group	Cumulative	
0.60–0.69	5	1.1	0.3	0.3	6.1
0.70–0.79	12	8.8	2.1	2.4	11.1
0.80–0.89	29	38.2	9.1	11.5	14.0
0.90–0.99	37	34.3	8.1	19.6	12.8
1.00–1.09	49	67.2	15.9	35.5	16.4
1.10–1.19	51	74.0	17.5	53.0	19.9
1.20–1.29	39	48.0	11.4	64.4	20.4
1.30–1.39	44	56.8	13.5	77.9	20.7
1.40–1.49	27	67.3	16.0	93.9	25.8
1.50–1.59	22	15.7	3.7	97.6	21.6
1.60–1.69	11	7.1	1.7	99.3	19.9
1.70–1.79	3	0.3	0.1	99.4	18.7
1.80–1.89	3	0.9	0.2	99.6	26.1
1.90–1.99	3	0.9	0.2	99.8	16.3
2.00–2.09	3	0.3	0.1	99.9	13.6
2.10–2.19	3	0.3	0.1	100.0	23.9
Total	341	421.2	100.0	100.0	19.2

TABLE VI-C.—Distribution by Adjusted Bond Yield Ratios, General Obligation Bonds Only

Adjusted Bond Yield Ratio Group (%)	No. of Issues	Bond Value			Av. Term (Yr.)
		$ (million)	Per Cent of Total		
			In Group	Cumulative	
0.60–0.69	5	1.1	0.7	0.7	6.1
0.70–0.79	12	8.8	5.6	6.3	11.1
0.80–0.89	23	27.7	17.5	23.8	13.3
0.90–0.99	29	21.5	13.6	37.4	13.3
1.00–1.09	31	31.1	19.7	57.1	15.5
1.10–1.19	23	14.2	9.0	66.1	16.7
1.20–1.29	10	16.0	10.2	76.3	23.0
1.30–1.39	8	8.2	5.2	81.5	13.3
1.40–1.49	5	27.6	17.5	99.0	30.7
1.50–1.59	7	1.1	0.7	99.7	18.3
1.60–1.69	2	0.1	0.1	99.8	9.9
1.70–1.79	—	—	—	—	—
1.80–1.89	1	0.1	0.1	99.9	13.5
1.90–1.99	—	—	—	—	—
2.00–2.09	—	—	—	—	—
2.10–2.19	1	0.1	0.1	100.0	34.0
Total	157	157.6	100.0	100.0	17.9

TABLE VII-A.—Distribution by Half-Year Periods, Revenue and General Obligation Bonds

Period	No. of Issues	Bond Value		Av. Term (Yr.)	Mean Yield (%)	Index[1] (%)
		$ (million)	% in Group			
1-6/51	50	46.6	11.1	16.2	1.93	1.81
7-12/51	27	31.8	7.5	16.7	2.41	2.07
1-6/52	29	37.4	8.9	16.1	2.45	2.08
7-12/52	26	18.3	4.3	18.3	3.22	2.28
1-6/53	28	48.1	11.4	25.1	4.10	2.66
7-12/53	25	43.8	10.4	18.6	3.47	2.82
1-6/54	65	90.9	21.6	17.7	2.88	2.47
7-12/54	91	104.3	24.8	21.3	2.93	2.32
Total	341	421.2	100.0	19.2	3.00	2.31

[1] Index of Municipal Bond Average Yields, the *Bond Buyer*.

TABLE VII-B.—Distribution by Half-Year Periods, Revenue Bonds Only

Period	No. of Issues	Bond Value		Av. Term (Yr.)	Mean Yield (%)	Index[1] (%)
		$ (million)	% in Group			
1-6/51	26	24.0	9.1	17.5	2.13	1.81
7-12/51	11	10.0	3.8	17.5	2.91	2.07
1-6/52	16	19.4	7.3	16.8	2.53	2.08
7-12/52	22	17.2	6.5	18.8	3.25	2.28
1-6/53	19	16.2	6.2	18.8	3.84	2.66
7-12/53	15	28.2	10.7	22.0	3.58	2.82
1-6/54	37	69.9	26.5	18.7	2.96	2.47
7-12/54	38	78.7	29.9	23.0	3.01	2.32
Total	184	263.6	100.0	19.9	3.02	2.31

[1] Index of Municipal Bond Average Yields, the *Bond Buyer*.

TABLE VII-C.—Distribution by Half-Year Periods, General Obligation Bonds Only

Period	No. of Issues	Bond Value		Av. Term (Yr.)	Mean Yield (%)	Index[1] (%)
		$ (million)	% in Group			
1-6/51	24	22.6	14.4	14.9	1.68	1.81
7-12/51	16	21.8	13.8	16.4	2.17	2.07
1-6/52	13	18.0	11.4	15.4	2.36	2.08
7-12/52	4	1.1	0.7	11.1	2.49	2.28
1-6/53	9	31.9	20.2	28.4	4.19	2.66
7-12/53	10	15.6	9.9	12.4	3.13	2.82
1-6/54	28	21.0	13.3	14.4	2.52	2.47
7-12/54	53	25.6	16.3	17.3	2.60	2.32
Total	157	157.6	100.0	17.9	2.95	2.31

[1] Index of Municipal Bond Average Yields, the *Bond Buyer*.

TABLE VIII.—Variation of Bond Yield with Term for Single Term Issues Only, Revenue and General Obligation Bonds

Term Group (Yr.)	No. of Issues	Bond Value			Actual Bond Yield		Adjusted Bond Yield Ratio		
		$ (million)	Per Cent of Total						
			In Group	Cumulative	Mean (%)	Median (%)	Mean	Median	Range
Under 5	5	2.8	3.5	3.5	1.99	1.99	1.10	0.94	0.75–1.50
5– 9.9	35	5.6	7.1	10.6	2.23	2.34	0.93	1.03	0.66–2.08
10–14.9	48	41.1	52.1	62.7	2.46	2.18	1.03	1.00	0.73–1.82
15–19.9	29	19.4	24.6	87.3	2.61	3.12	1.20	1.33	0.80–2.08
20–24.9	10	7.8	9.9	97.2	3.73	3.59	1.55	1.54	1.25–2.10
25–29.9	4	2.1	2.7	99.9	3.60	3.57	1.61	1.54	1.48–1.88
30 or over	2	0.1	0.1	100.0	3.67	3.62	2.00	2.03	1.95–2.10
Total	133	78.9	100.0	100.0	2.74	2.49	1.19	1.13	0.66–2.10

TABLE IX.—Sewage Treatment Works Construction Awards Average for Years 1952–53–54 Distributed by Population Groups [1]

Population Group (thousand)	New Plants		Additions, Enlargements, Replacements, etc.		All Projects		Total Cost		
							$ (million)	Per Cent of Total	
	No. Projects	Cost ($, million)	No. Projects	Cost ($, million)	No.	Per Cent of Total		In Group	Cumulative
Under 2.5	204	14.6	66	3.4	270	44	18.0	10	10
2.5–5	45	8.9	37	3.7	82	13	12.6	7	17
5–10	36	10.7	39	7.0	75	12	17.7	9	26
10–25	27	13.6	38	8.6	65	11	22.2	12	38
25–50	10	8.7	19	5.7	29	5	14.4	8	46
50–100	6	13.1	20	14.9	26	4	28.0	15	61
100–250	5	16.9	20	10.8	25	4	27.7	15	76
250–500	1	16.8	14	7.0	15	2	23.8	13	89
500–1,000	1	1.9	5	4.9	6	1	6.8	4	93
Over 1,000	1	.7	21	13.3	22	4	14.0	7	100
Total	336	105.9	279	79.3	615	100	185.2	100	100

[1] See reference (2).

DUAL AERATION AS A RUGGED ACTIVATED SLUDGE PROCESS *

By L. S. Kraus

Chemist, Greater Peoria Sanitary District, Peoria, Ill.

Since the basic conception of the activated sludge process by Ardern and Lockett in 1913, its development has been gradual but continuous. In their laboratory studies of sewage aeration, the aeration phase was continued until oxidation was complete. The solids were then allowed to settle and the purified sewage was decanted. Additional raw sewage was added to the deposited settled solids and the cycle of aeration, settling, and decantation was repeated many times. An evaluation of the process based on these studies was published in 1914 (1). This paper contains the following statements:

"It was found that as the amount of the deposited matter increased, the time for each succeeding oxidation gradually diminished until eventually it was possible to completely oxidize a fresh sample of crude sewage within twenty-four hours.

"For reference purposes and failing a better term, the deposited solids resulting from the complete oxidation of sewage have been designated 'activated sludge.'"

From that time to the present, the development of equipment and procedure for carrying out the basic concepts of activated sludge treatment has resulted in many modifications. The modifications are intended to reduce capital and operating costs and to overcome difficulties in operating procedures. While much has been accomplished in understanding the fundamentals of the biochemistry and microbiology involved in the process, after even 40 years of study and use the mechanisms and chemistry involved are not fully understood.

It is the aim of this paper to discuss recent studies of problems at the Peoria activated sludge plant, and to indicate the direction in which the data observed seem to point. A review of certain concepts is presented in order to better understand these developments.

Mechanism of Purification

It is not clear whether Ardern and Lockett had in mind the association of their term "activated sludge" with the phenomenon of adsorption or whether they intended to apply Webster's definition—"to make active." Certainly the latter definition would describe the sludge they produced by repeated fill and draw laboratory experiments, since their process resulted in the production of a sludge which could finally effect substantial nitrification in 6 to 9 hr. of a sewage that required aeration for five weeks in the initial experiment.

It is generally accepted that adsorption plays an important role in the removal of organic materials from the sewage by the sludge. Investigators have at least established the fact that some of the organic compounds, dispersed, colloidal and dissolved, enter the zoogloeate matrix of the sludge, and ultimately reach a concentration near saturation. The sludge is then incapable of further purification until the materials so incorporated in the sludge have been removed biochemically. The organic materials so removed are converted to oxidative

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products (probably carbon dioxide and water), biological exudates and microorganisms. The organisms and their surrounding exudates, referred to as zoogloea, constitute the active purifying media in the sludge. The zoogloea, together with occluded sewage suspended solids, constitutes the activated sludge. The volume of the activated sludge results largely from the zoogloea it contains, the sewage suspended solids being primarily responsible for its weight (expressed on a moisture-free basis).

The activated sludge process involves the removal of organic materials from sewage (a) by aerating the sewage with activated sludge, and (b) by the subsequent removal of the sludge from the purified sewage by settling. The first step is brought about by action of the sludge zoogloea, and the second step is responsive to the weight and density of the suspended solids contained in the sludge. For the process to function properly, it is necessary that both of these factors be under control.

Ardern and Lockett pointed out in their 1914 paper that "in order to maintain the sludge at its highest efficiency it is necessary that there should not be at any time an accumulation of unoxidized sewage solids." They also stated: "It is not necessary that the sewage should be kept in contact with the activated sludge until such conditions obtain, as its activity may be maintained by suitable aeration of the activated sludge alone."

In conventional operation of the activated sludge process, both sewage purification and sludge reactivation take place in the same aeration tank. As the process is practiced at Peoria, Ill., a separate aeration tank is used for continuous aeration of a part of the activated sludge. A sufficient portion of the activated sludge is circulated through this tank to maintain sludge activity. At the same time digested sludge is added to this activated sludge.

Control of Sludge Index

The purpose of adding digested sludge to the activated sludge in the separate aeration tank is to control the sludge settleability. The digested sludge will mix with the activated sludge and remain dispersed in the mixture. Analysis of the mixture shows an increased settleability and a decreased sludge volume index (S.V.I.). The resulting change in S.V.I. is proportional to the weighted average of the S.V.I. of the two components.

a. Activated sludge

Rate of flow	1.0 m.g.d.
Suspended solids	10,000 p.p.m.
S.V.I.	100

b. Digested sludge

Rate of flow	0.1 m.g.d.
Suspended solids	50,000 p.p.m.
S.V.I.	20

c. Mixture

Rate of flow $1.0 + 0.1 = 1.1$ m.g.d.

S.V.I. = I

$$1.0 \times 10{,}000 \times 100 + 0.1 \times 50{,}000 \times 20 = (1.0 \times 10{,}000 + 0.1 \times 50{,}000) I$$

$$I = \frac{1{,}000{,}000 + 100{,}000}{10{,}000 + 5{,}000} = \frac{1{,}100{,}000}{15{,}000} = 73.3$$

Suspended solids of mixture = S

$$S = \frac{1.0 \times 10{,}000 + 0.1 \times 50{,}000}{1.0 + 0.1} = 13{,}600 \text{ p.p.m.}$$

The foregoing example is presented for illustrative purposes. In plant operation, the quantity of digested sludge added need be sufficient only to balance the tendency of the sludge index to increase.

Activated Sludge Bulking

Bulking has been recognized as a problem in operation of the activated

sludge process since the late 1920's, particularly in sewage treatment plants receiving discharges of industrial wastes. Bulking, or high sludge volume index activated sludge, has led those operating and designing plants to consider the treatment process a delicate and sensitive one, which should be used only when variations in loading are slight. The thought prevails that if the process is overloaded with respect to B.O.D. or retention period, bulking will ensue and the process efficiency will be materially reduced. For this reason, the acceptance of certain industrial wastes for treatment in municipal activated sludge plants has been thought undesirable.

The late C. C. Ruchhoft and associates in 1939 published an explanation of the bulking phenomenon (2). In effect, their report indicated that two processes are proceeding simultaneously in the purification process; one a process of oxidation of compounds to carbon dioxide and water, and the other a process of synthesis of zoogloea. It is the latter process which produces the materials having low density and high sludge volume index. When industrial wastes contain substantial quantities of dissolved organic matter, however, the synthesis of microorganisms and zoogloea may constitute a major factor.

Plant operating data which provide a comparison of activated sludge wasted and suspended solids removed indicate that synthesis can amount to as much as one-third of the suspended solids added. When synthesis takes place to this extent, an increase in sludge index is observed. Some degree of compensation for this increasing sludge index must be provided. This can be accomplished by prolonged aeration which results in oxidizing some of the zoogloea and thus produces a slight lowering of the sludge index, or it may be accomplished by adding readily dispersed solids of low S.V.I.

The treatment employed at Peoria

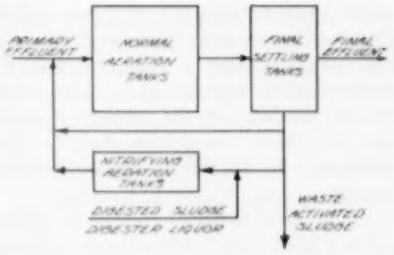

FIGURE 1.—Flow diagram of the activated sludge process.

uses digested sludge for this purpose, together with aeration which produces an activated sludge of considerable activity and one having a low sludge index. By this process, the digested sludge is converted to activated sludge and subsequently is added to the mixture of sewage and activated sludge in the aeration tanks. Figure 1 is a flow diagram of the process (3).

The following data indicate the degree to which the S.V.I. can be controlled by the addition of digested sludge in a treatment process that normally would have values above 100, with maxima in the order of 300 to 400. During the year 1954, average S.V.I. at the Peoria plant was 44 with a maximum monthly average of 51 and a minimum monthly average of 37. Daily data are tabulated below:

S.V.I. Range	Number of Days
35–40	70
40–50	214
50–60	70
60–70	10
72	1

Activated Sludge Clarification

Another factor in the purification cycle which has given the activated sludge process the reputation of being sensitive to "shock" loadings is the loss of clarifying ability which corresponds to periods of low dissolved oxygen in the aeration tanks. In small activated sludge plants it is usually impossible to vary the quantity of air applied every few hours in order to

assure maintenance of an appreciable dissolved oxygen content in the aeration tank effluent. This problem is particularly significant when the B.O.D. content of the sewage is subject to sharp variations due to the discharge of industrial wastes to the sewage.

In the conventional treatment plant a shock load results not only in a sharp increase in sludge volume index, but also in a loss of dissolved oxygen in the aeration tanks; in addition, an attendant reduction occurs in the number of clarifying microorganisms. Following such an occurrence, a period up to one week may be required to re-establish the clarifying ability of the sludge.

The Peoria situation is one in which shock loads on the sewage treatment process are frequent and sustained. In a community of 135,000 population, the sewage population equivalent value frequently exceeds 450,000. The peak hourly rates exceed a 600,000 population equivalent value. It is obvious that under such loadings the loss of clarification would be a problem, even though dissolved oxygen determinations are made for control at intervals of four hours. An operator can apply all the available air to the aeration tanks and find that the dissolved oxygen content in the effluent from these tanks is approaching zero. Not only has the clarity of the effluent been destroyed, but after the shock load has been removed and the dissolved oxygen content of the aeration tank liquor has returned to normal the loss of clarification still persists. Many days may be required to re-establish the lost organisms; thus, if the shock load recurs every few days the inadequacy of the purification process is apparent.

The effect of low dissolved oxygen and resulting loss of clarification is minimized in the activated sludge process as practiced at Peoria. During four weekdays, Tuesday through Friday, the dissolved oxygen content of the aeration tank effluent falls below 0.5 p.p.m. for a period of 8 to 12 hr. At the same time, the effluent undergoes some loss of clarification, but as soon as adequate dissolved oxygen is

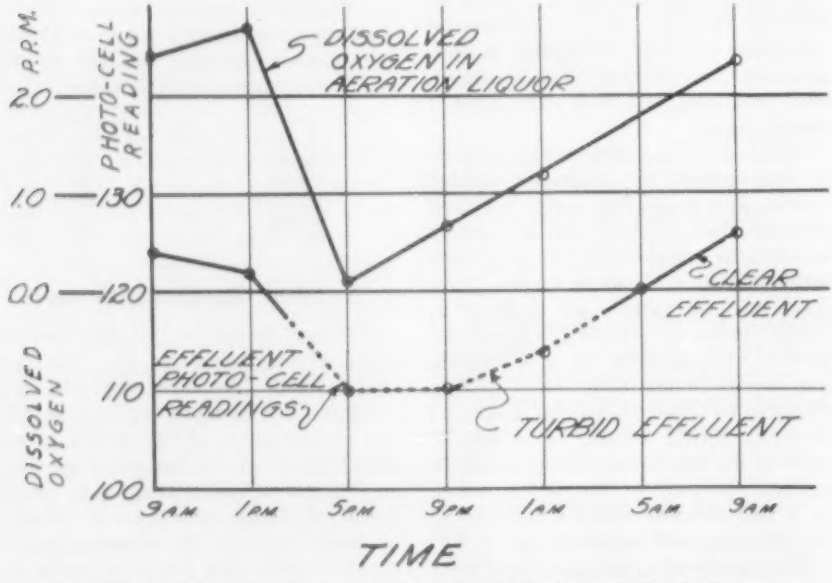

FIGURE 2.—Effect of typical shock load on clarification and dissolved oxygen.

regained the clarification is re-established.

Figure 2 illustrates these conditions on a typical day. This graph shows variations at intervals of four hours in photoelectric cell measurements of the final effluent turbidity, and approximate (colorimetric) values of dissolved oxygen in the aeration tank effluent. Note that as the dissolved oxygen is reduced the turbidity is increased and lower photoelectric cell readings are obtained. During the period when the general dissolved oxygen concentration is less than 1.0 p.p.m., the concentration in some aeration tank units falls to zero. As the dissolved oxygen content again increases, the turbidity is reduced and the photoelectric cell reading rises.

That the day illustrated, May 11, 1955, is typical of what might be termed "shock load" conditions is indicated by the following tabulation:

Aeration tank loading
  Including nitrifying aeration tank—102.1 lb. B.O.D. per 1,000 cu. ft. per day.
  Without nitrifying aeration tank—153.1 lb. B.O.D. per 1,000 cu. ft. per day.
Retention period in aeration tanks—2.39 hr.
Air—466 cu. ft. per lb. applied B.O.D.
Overall B.O.D. removal—91.5 per cent.

Compare the above loadings with the 33 lb. B.O.D. per 1,000 cu. ft. of aeration tanks used in Illinois as a design factor, and the 466 cu. ft. of air per pound of applied B.O.D. with the value of 700 commonly considered efficient operation.

In the conventional process, a load such as that illustrated would result in a loss of clarification and a sharp rise in sludge index. The sludge index value was 41 on May 10th and 43 on May 12th, a minute change which emphasizes the stability of the activated sludge process and its capacity for absorbing shock loads.

Responsibility for the rapid recovery of clarification following the re-establishment of dissolved oxygen content in the aeration liquor effluent is due, in our opinion, to the presence of suitable clarifying microorganisms in the sludge nitrifying aeration tank. The cultivation of an active and readily settleable sludge in this tank is independent of conditions in the "flow through" aeration tanks.

Maintenance of Dissolved Oxygen

As the load on the Peoria activated sludge sewage treatment works increased, greater quantities of dissolved oxygen were required. A study of the efficiency of oxygen absorption, as indicated by the residual dissolved oxygen in the air released from the tank, is summarized in Figure 3. Accurate data under plant conditions are very difficult to obtain; however, Figure 3 is considered a typical approximation summarized from 47 determinations made in the spiral flow aeration tanks. It is apparent that as the rate of application of air is increased, the efficiency of absorption of oxygen decreases. Obviously, if the aeration tanks were to handle increased loadings, the development of improved methods of air application would be required.

It is a generally accepted premise that air should be introduced into the aeration tank near the tank bottom, and that this air be diffused into small bubbles. In order to prolong diffuser life, and to keep the pressure loss through the diffuser low, the air must be as free as possible from dust and other dispersed particles.

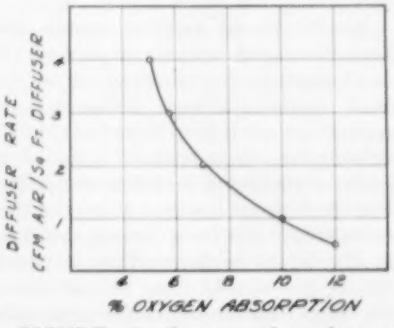

FIGURE 3.—Oxygen absorption as measured by analysis of air released from aeration tank for varying rates of air per diffuser.

When an air bubble is released in water, the rate of solution of oxygen is considered proportional, among other factors, to the depth of submergence and time of contact. It is also considered that solubility varies inversely to the temperature, the bubble size, and the degree of saturation of the dissolved oxygen in solution. In addition, it is considered probable that the film of liquid in contact with the air is instantly saturated with dissolved oxygen and that the over-all rate of solution is largely dependent on the rate at which the saturated film is transferred or diffused into the surrounding body of the liquid. This transfer or diffusion is increased as the turbulence of the liquid increases.

Factors over which the designer of aeration equipment has some control are bubble size, depth of submergence, contact time and turbulence. Experiments utilizing one-fourth of the Peoria aeration tank capacity have led to the belief that, of these variables, turbulence is the most important. Proper application of air has made it possible to effect a considerable tank turbulence, and also to increase bubble-liquid contact time. These experiments have revealed that turbulence can be produced with air admitted well above the tank bottom, and that this portion of the air need not be diffused into small bubbles.

A Dual Aeration System

At Peoria, an aeration system has been developed wherein a part of the total applied air is admitted at the tank bottom through diffusers, and part of the air is distributed at shallow submergence in a manner designed to create a maximum turbulent condition. The turbulence produced by the distributed air creates a violent agitation at the liquid surface. This increases the oxygen uptake from the air above the liquid surface and also increases the rate of oxygen absorption from the air admitted in small bubbles near the tank bottom. Not only is the rate of dissolved oxygen transfer from the saturated film at the bubble surface to the liquid body increased, but also the path of the bubble is lengthened, thus increasing bubble contact time.

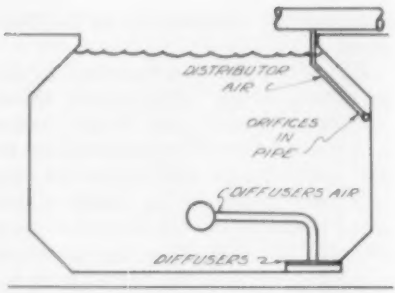

FIGURE 4.—Parallel flow distributed air experimental unit.

Figures 4 and 5 are sketches which indicate the manner in which the experiments have been carried out. Air is distributed through orifices in piping immediately adjacent to the tank wall, and at a submergence approximately one-third of the liquid depth in the tank. The rate of application of the distributed air is just sufficient to create violent wave action on the tank surface.

Figure 4 illustrates application of the distributed air on the same side as the diffused air, termed parallel flow; Figure 5 illustrates application of distributed air on the side opposite to the diffused air, termed counter flow.

Parallel flow design was found to be

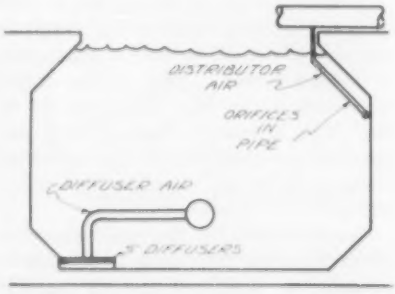

FIGURE 5.—Counterflow distributed air experimental unit.

slightly less effective than counter flow in oxygen absorptive efficiency but produced increased tank velocities, particularly at the surface, and is recommended for the operation of nitrifying aeration tanks when high sludge concentrations are being aerated. The counterflow design is slightly more effective in oxygen absorption efficiency, since it reduces bottom velocities and increases the distance of bubble travel from the diffusers at the tank bottom. The latter type of aeration is suggested for the normal aeration tanks.

Two unearned advantages of the dual aeration system are lower power requirements and reduced air cleaning needs. The power required for aeration is directly proportional to the discharge pressure of the blower. Reducing the submergence of a portion of the air lowers the horsepower requirements. Two air systems, one for the diffused air and one for the distributed air, are required for this operation. In addition to the lower power requirement, there is no need whatever for filtering the distributed air.

The experiments described above were conducted in one battery of aeration units of 195,000 cu. ft. capacity. The first series of tests extended over a period of 110 days during the winter months, when the over-all efficiency of treatment required by the Illinois State Sanitary Water Board was 80 per cent. The experiment was conducted to determine the maximum loading that could be applied to the battery equipped with distributed air. The following tabulation indicates the results obtained in these experiments:

Period	A	B	C
Number of days	110	61	10
Aeration tank loading applied (Lb. B.O.D./1,000 cu. ft./day)	91.4	135.4	170.3
Aeration period (hr.)	2.21	1.61	1.34
Diffused air (mil. cu. ft./day)	2.4	6.0	6.5
Distributed air (mil. cu. ft./day)	7.3	5.4	4.5
Total air (cu. ft./lb., applied B.O.D.)	546	431	451
Total air (cu. ft./lb., applied B.O.D.)*	401	294	282
B.O.D. removal, entire plant (%)	86.3	86.8	90.1

* Corrected for submergence.

Discussion of Results

During period A, two of the three aeration bays in the experimental battery were equipped with parallel flow distributed air and one with counter flow distributed air; in all units distributors were located at 9-ft. submergence, with normal diffusers at 15-ft. depth. The air applied to the diffusers was held at a minimum and the distributed air maintained at a rate considered rather high. The flow through the tank was gradually increased to a proper level and data on the operation was obtained.

Unfortunately it was not possible to settle separately the effluent of this battery of aeration units in the final settling tanks of the treatment plant. It was observed, however, that those final settling tanks to which effluent of the experimental battery was discharged were superior in appearance to those tanks receiving the remaining flow only.

Periods B and C represent data using counter flow distributed air at 5-ft. submergence.

An inspection of the data discloses that very short aeration periods and extremely high loadings may be employed with good total air economy. The aeration period is computed as an average displacement time for sewage plus return sludge. The value "total air corrected for submergence" is a new expression introduced to demonstrate the advantage of reduced power requirements with part of the air at lower submergence. A power requirement is not strictly proportional to the submergence, since head loss in piping, diffusers and distributors must be considered. The value does indicate, however, the order of saving in power costs that can be attained by using the combined process of sludge index control and dual aeration with diffused and distributed air.

Significant also is the observation that, in these experiments, the reduced submergence of the distributed air did

not increase the air requirement (contrary to what is generally thought to be the case). The over-all air efficiency of this process indicates air requirements lower than usual.

The periods A and B, respectively 110 and 61 days in length, are indicative of purification results that can be attained with this process. Period C, of only 10-days' duration, is presented merely to suggest the potentialities of the process. During the 10 days, 90 per cent of the total raw sewage flow was passed through this battery of aeration units. The hydraulic limitations of sluice gates and piping prevented extended operation under the test conditions. It is intended that these limitations will be removed, and that the study will be continued; after a substantial period of operation, the results will be reported.

A comparison of the above data with design factors in common use results in the following observations:

1. Using the dual aeration system aeration tank loading, in terms of pounds of applied B.O.D. per 1,000 cu. ft. per day, may be increased at least two to three times more than that of the normal design value (33 lb. per 1,000 cu. ft. per day).
2. An aeration period of one-third that normally considered necessary is possible.
3. Aeration facilities installed on a unit volume basis must be considerably increased above those normally provided.

Additional Process Characteristics

One of the disadvantages in operation of the conventional activated sludge process is the low concentration of solids in the sludge wasted to the digesters. If 100 S.V.I. activated sludge is wasted to primary settling tanks, the sludge pumped from these tanks will contain about 3 per cent total solids. If the S.V.I. is 200, the primary tank sludge will be reduced in total solids concentration to about 2 per cent. During 1954 the annual average of total solids from the Peoria primary settling tanks was 5.1 per cent. This high solids concentration reduces the volume of sludge pumped to digesters, reduces the digester heating requirements and appreciably affects the volume of sludge discharged for final disposal.

The digester supernatant liquor problem is completely eliminated by adding the total volume of liquor to the nitrifying aeration tank.

With low S.V.I. activated sludge there is an increased ability to maintain high suspended solids in the aeration tanks; this condition appears desirable in solving the frothing problem.

Summary

Data are presented in this paper to evaluate a dual aeration system. This modification of the activated sludge process as practiced at Peoria has the following characteristics:

1. Ability to control the activated sludge S.V.I., and to maintain the index at a low value.
2. Ability to treat industrial wastes in shock loads.
3. Ability of the activated sludge to regain its clarifying properties immediately after shock loads have been received.
4. Ability to resist "bulking" following application of shock loads.
5. Ability to maintain high suspended solids concentration in the aeration tanks.
6. Ability to produce higher concentrations of suspended solids in waste activated sludge, primary settling tank sludge and waste digested sludge.
7. Ability to maintain a high degree of stability in the activated sludge, thus simplifying plant operation.

The experimental data presented relating to the dual aeration system indicate that:

1. Dual aeration, diffused air in combination with properly applied distributed air, is an efficient means of aeration.

2. Dual aeration, combined with sludge index control in a nitrifying aeration tank, results in:

a. Ability to effectively treat high B.O.D. loadings.
b. Effective treatment using low aeration periods.
c. Effective treatment using low air requirements, thus reducing power costs.

3. The distributed air process has the following advantages:

a. Need for filtering air is eliminated.
b. Low submergence results in a saving of power required for the air supply.
c. Turbulence produced increases the oxygen absorption from diffused air and also from the liquid surface.

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USPHS SANITARY ENGINEERING TRAINING PROGRAMS

The Sanitary Engineering Center of the U. S. Public Health Service has announced a series of training programs to be given during the first six months of 1956 at Cincinnati, Ohio.

Advanced sanitation training courses to be offered include the following:

Jan. 30–Feb. 3	Problems of Radioactivity in Water Works
Feb. 6–17	Air Pollution Atmospheric Sampling and Analytical Procedures
Mar. 5–16	Advanced Training for Sanitary Engineers in Water Pollution Abatement Programs
Mar. 20–21	Conference on Organization and Administration of Local Air Pollution Control Programs
April 9–13	Air Pollution Source Sampling Theory and Techniques
April 16–27	Basic Course in Radiological Health
April 30–May 4	Environmental Radiation Sanitation
May 8–10	Analyses of Metals and Cyanides in Industrial Wastes
May 14–18	Air Pollution Meteorology
May 22–25	Advanced Training for Aquatic Biologists in Pollution Control

Additional information may be secured by writing to the Chief, Training, Robert A. Taft, Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio, or through any USPHS Regional Office.

A LABORATORY EVALUATION OF HIGH-RATE SLUDGE DIGESTION *

By C. N. Sawyer and H. K. Roy

Professor of Sanitary Chemistry and Research Assistant in Sanitary Engineering, Respectively, Massachusetts Institute of Technology, Cambridge, Mass.

The possibility of increasing the capacity of anaerobic sewage sludge digestion units has been under laboratory, pilot and full scale plant investigation in the United States for a number of years. From reports published to date, it is apparent that full scale digestion units have been operated satisfactorily in the range of 11 to 14 day detention periods at volatile solids loadings ranging from .18 to .25 lb. per cubic foot per day. On the basis of laboratory and pilot scale investigations, it appears possible to operate full-scale units at detention periods of five days or less with volatile solids loadings up to 0.50 lb. per cubic foot per day.

High-Rate Digestion Experience

Morgan (1) has reported on pilot scale studies of one year's duration in which satisfactory digester operation was obtained with volatile solids loadings of 5 to 7 times those normally used and with detention periods as low as 7 to 8 days. Blodgett (2) has operated a plant scale digester at loading rates about four times conventional.

Torpey (3) (4) has demonstrated the ability of one digestion tank to handle all sludge produced at the Bowery Bay plant, when the sludge is properly pre-thickened. Previously, difficulty had been encountered at the plant when using four tanks. Volatile solids loadings ranged up to five times conventional, and the detention time was as low as 11 days. In subsequent pilot scale studies, involving feeding at two hour intervals, Torpey has demonstrated a high degree of operating stability may be maintained at volatile solids loadings about 12 times conventional, using a detention period slightly under four days.

Schmidt (5) was successful in operating laboratory units at 11 days detention over a wide range of solids loadings, but encountered trouble at an 8-day detention period when feeding a sludge having two per cent solids. Garber (6) has reported that primary digesters at the Hyperion plant have handled volatile solids loadings of 0.25 lb. per cubic foot per day at detention periods ranging from 12 to 14 days.

Summary of Critical Requirements

Successful operation of high-rate sewage sludge digestion units at maximum loading appears to depend upon three critical requirements:

1. Some form of continuous mixing, to keep the entire contents of the digestion tank in a "mixed liquor" condition to prevent separation of solids in a scum layer.
2. Feeding a sludge as concentrated as possible.
3. Feeding on a basis as nearly continuous as possible.

The first of these requirements is absolutely essential; normally it allows increasing the loading by a factor of 5 or 6. Concentration of the sludge

* Presented at 1955 Joint Meeting, New England Sewage and Industrial Wastes Assn. and the New York Sewage and Industrial Wastes Assn.; Albany, N. Y.; June 13–14, 1955.

allows increased loading in direct proportion to the thickening accomplished. No quantitative information exists on the benefits of continuous feeding versus twice daily feeding but, undoubtedly, its benefit increases as the detention period decreases. Laboratory investigations indicate a 6-day detention period to be about the minimum for twice daily feedings.

At this time the ability of sludge digestion units equipped with adequate mixing facilities to operate at loading rates 4 to 7 times conventional appears to be amply demonstrated. Since the digestion of sewage sludge is a subject of many facets, it becomes important that answers be obtained to questions which will occur to designing engineers and public health officials. A few of these questions are:

1. Quality and character of sludge produced
   a. Volatile content
   b. Grease content
   c. Fertilizing values
2. Gas production
   a. Quantity
   b. Fuel value
3. Survival of pathogenic organisms

It was the purpose of this research to operate a series of digestion units in parallel, in order to provide answers to some of these questions. Studies on the survival of pathogenic organisms are incomplete, and are not presented at this time.

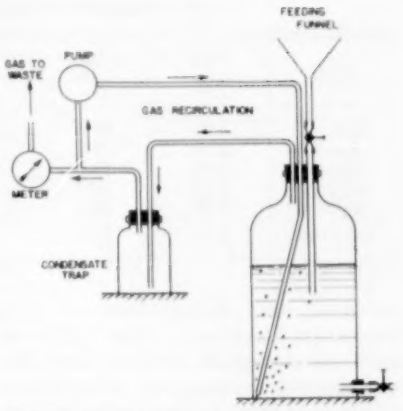

FIGURE 1.—Schematic layout of laboratory sludge digestion unit.

Method of Study

Five digestion units were operated in parallel, all being fed from the same supply of sludge. Each digester had an operating capacity of 6 l., and sludge was fed twice daily at approximately 12-hr. intervals to give theoretical detention periods of 6, 8, 10, 15 and 20 days. It had been planned to operate one digestion unit on a 5-day detention time; attempts to do so were unsuccessful on the twice daily feeding

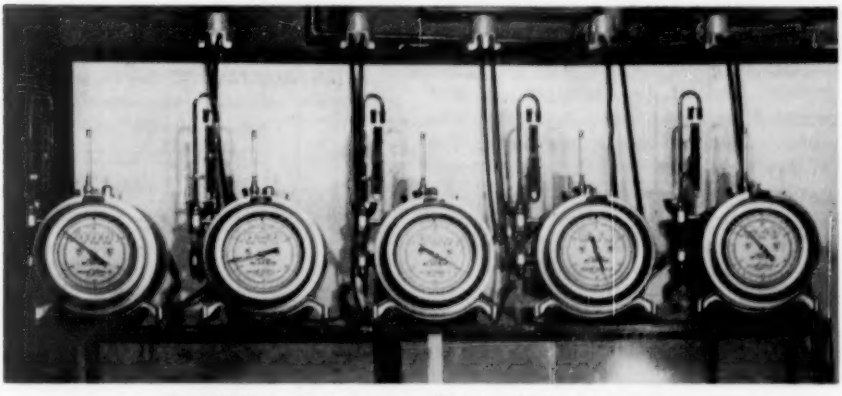

FIGURE 2.—Gas meters and gas recirculation pumps.

TABLE I.—Composition of Raw Sludge

Date (1955)	Total Solids (%)	Volatile Solids (%)	pH	Alkalinity (p.p.m.)	Volatile Acids (p.p.m.)	Grease (%)
Mar. 3	5.20	69.3	5.55	1175	840	11.85
Mar. 17	3.52	75.0	5.80	1225	1040	16.25
Apr. 5	4.90	78.0	5.65	1085	1050	16.80
Apr. 23	5.40	68.0	5.90	1290	1000	14.10
May 5	3.10	82.0	5.70	430	470	13.40
Average	4.42	74.5		1040	980	14.50

schedule, even though loadings were gradually increased. Each digestion unit was equipped with a small diaphragm compressor for recirculation of gas to provide internal mixing. Gas volume measurements were made by means of wet test meters. Figure 1 is a schematic drawing of the digestion assemblies, and Figure 2 shows the wet test meters and gas recirculation pumps which were mounted outside of the room housing the digesters.

Temperature of the digester operating room was maintained between 33° and 40° C. An amount of mixed liquor, equal to the volume of sludge to be fed, was withdrawn from each digester just prior to feeding. All analyses were conducted in accordance with Standard Methods (7).

Sludge used in the studies was obtained at intervals of 12 to 18 days from the Nut Island Sewage Treatment Plant, Boston, Mass. The sludge was comminuted by passing through a household type garbage grinder to facilitate feeding operations. The supply of sludge was stored at 4° C.; before feeding to digesters, it was warmed to about 35° C. Sludge was obtained on five occasions during the 77-day period covered by the investigations being reported.

The composition of the sludges as fed is given in Table I. A considerable range in composition was encountered, but these variations were tolerated by the digesters even at the 6-day detention period.

The loadings applied to the digestion units, shown in Table II, ranged from about two times conventional in the 20-day digester to about seven times in the 6-day digester. Because of limited space it was not feasible to operate a digestion unit in the conventional loading range of about 0.05 lb. of volatile solids per cubic foot per day, using a detention period of 40 days.

All digestion units were started by using a digested sewage sludge containing four per cent total solids. Feedings were started on a 20-day detention basis and gradually increased at weekly intervals until all units were operating at the desired detention period. After the 6-day digester had operated at its proper detention period for one week, routine analyses and observations were started.

Experimental Results

Composition of Digested Sludge

The sludges withdrawn from the digestion units were analyzed for total and volatile solids, volatile acids, alka-

TABLE II.—Loadings on Digestion Units (Lb./cu. ft./day—75-Day Period)

Item	Digester Detention Period, Days				
	6	8	10	15	20
Tot. Sol.					
Max.	.56	.42	.34	.22	.17
Min.	.32	.24	.19	.13	.10
Av.	.47	.35	.28	.19	.14
Vol. Sol.					
Max.	.38	.29	.23	.15	.11
Min.	.26	.19	.16	.10	.08
Av.	.35	.26	.21	.14	.10

TABLE III.—Composition of Withdrawn Digested Sludge[1]

Determination	Digester Detention Period, Days				
	6	8	10	15	20
Total solids (%)	3.15	3.05	2.99	2.92	2.77
Volatile solids (%)	58.3	57.8	56.4	55.6	55.2
Vol. acids (p.p.m.)	270	140	110	110	110
Alk. (p.p.m.)	2540	2640	2720	2920	2930
pH	7.0	7.05	7.15	7.30	7.45
Ammonia-N (p.p.m.)	400	418	434	464	465
Grease (%)	9.50	8.85	8.05	7.15	6.65

[1] Based on a 75-day period; average of 11 samples.

linity, pH, ammonia nitrogen and grease content. A total of 11 samples were collected at weekly intervals. The results obtained have been averaged and are shown in Table III.

These data show that the concentration of total solids, volatile solids and grease content of the digested sludge increased quite materially as the detention period decreased. Volatile acids were somewhat higher in the sludge from the 6-day digester, but not abnormally so. The alkalinity, pH and ammonia nitrogen all decreased with decreasing detention time, indicating a significant reduction in the degradation of protein matter (the principal source of ammonia nitrogen and major source of alkalinity).

Destruction of Organic Matter

The degree of destruction of organic matter during digestion at the various detention times is shown in Table IV and Figure 3. Destruction of volatile matter ranged from 52.2 per cent at the 6-day detention period to 58.2 per cent at the 20-day detention period. The destruction was 89.6 per cent as complete in the 6-day as in the 20-day digester. A similar reduction in gas yield would be expected. Grease destruction varied from 53.0 per cent in the 6-day digester to 71.4 per cent in the 20-day digester, indicating a serious decrease with decreased detention time. On the other hand, protein destruction (as indicated from ammonia nitrogen data) was 86 per cent as great in the 6-day digester as in the 20-day unit, paralleling quite closely the overall volatile solids reduction.

Composition of Sludge Gas

The quality of the gas produced during sludge digestion is of particular in-

TABLE IV.—Destruction of Organic Matter[1]

Item	Digester Detention Period, Days				
	6	8	10	15	20
Volatile Matter					
Per cent	52.2	53.5	55.8	57.2	58.2
Per cent of 20-day	89.6	91.8	95.8	98.3	—
Grease					
Per cent	53.0	57.8	62.8	67.1	71.4
Per cent of 20-day	74.2	80.8	87.4	94.0	—
Indicated Protein					
Destruction[2] (% of 20-day)	86.0	89.8	93.2	99.7	—

[1] Based on a 75-day period.
[2] Based on ammonia-N content of digested sludges.

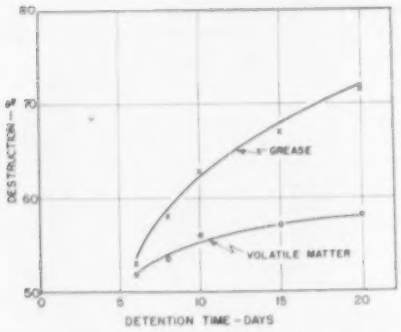

FIGURE 3.—Destruction of organic matter by digestion.

terest when the gas is used for power purposes. The data obtained in these studies (Table V) show the carbon dioxide content to gradually increase and the methane content to decrease as the digestion time is decreased. There was no significant effect on the hydrogen content of the gas.

Gas Production

The operation of five digestion units in parallel, while feeding all from the same supply of sludge, provided an excellent opportunity to gain information on gas yield in relation to the detention period in the digester. These data, presented in Table VI, show that 18.6 l. of gas were produced per liter of sludge fed to the 6-day digester, and 20.3 l. from each liter of sludge fed to the 20-day digester. Thus, 91.5 per cent as much gas was produced from the 6-day as from the 20-day digestion unit. However, it has been shown in Table V that the composition of the gas varied considerably. Therefore, the yields of carbon dioxide and methane were calculated separately. It will be noted that the yield of carbon dioxide was essentially uniform from all digestion units and the real sacrifice in gas production was in terms of methane. The 6-day digester yielded 88.8 per cent as much per unit of sludge fed as did the 20-day unit.

It is the usual practice to relate gas production to volatile solids charged to the digestion units or to volatile solids destroyed. This practice has been followed in Table VII. The gas yield per pound of volatile solids charged to the digestion units varied from 8.9 to 9.7 cu. ft., and increased with increased detention time. The gas yield per pound of volatile matter destroyed varied from 16.5 to 17.1 cu. ft. Both sets of values correspond closely with those expected in actual practice.

TABLE V.—Composition of Sludge Gas[1]

Gas	Digester Detention Period, Days				
	6	8	10	15	20
Carbon dioxide (%)	37.9	37.0	37.0	35.5	34.8
Methane (%)	55.2	56.6	56.8	57.6	57.2
Hydrogen (%)	2.6	2.9	2.8	2.6	2.4

[1] Based on a 30-day period; average of 7 samples.

TABLE VI.—Gas Production Versus Detention Time[1]

Item	Digester Detention Period, Days				
	6	8	10	15	20
Total yield (l.)	1430	1109	893	616	470
Liters/day	18.6	14.4	11.6	8.0	6.1
Liters/l. sludge	18.6	19.2	19.4	20.0	20.3
Carbon dioxide (l./l. sludge)	7.05	7.10	7.18	7.10	7.07
Methane (l./l. sludge)	10.3	10.9	11.0	11.5	11.6
Per cent of 20-day	88.8	93.8	94.7	99.0	—

[1] Based on a 77-day period.

TABLE VII.—Gas Production Versus Solids[1]

Item	Digester Detention Period, Days				
	6	8	10	15	20
Gas yield (cu. ft.)	50.6	39.1	31.5	21.8	16.6
Vol. solids fed (lb.)	5.70	4.27	3.42	2.28	1.71
Gas (cu. ft./lb. vol.)	8.90	9.15	9.22	9.56	9.72
Vol. solids destroyed (lb.)	2.98	2.29	1.91	1.30	1.00
Gas (cu. ft./lb. vol. destroyed)	17.0	17.1	16.5	16.8	16.6

[1] Based on a 77-day period.

Fertilizing Value of Digested Sludges

In many localities digested sludge is disposed of by sale to fertilizer producers. Consequently, the fertilizing value of the sludge is of real concern. Normally, the sludge is sold on a guaranteed nitrogen and phosphorus content. Grease content may also be a consideration.

Sludge samples were collected from each of the digestion units just prior to changing to a new supply of raw sludge. After filtration and drying, the samples were prepared for analysis and the nitrogen and phosphorus content was determined. The values are given in Table VIII, as are the values for grease content which was determined on the weekly routine samples. It will be noted that the nitrogen and phosphorus content of the sludges remained remarkably uniform at all digestion times—except for the sludge from the 6-day digester, which showed a significant decline in nitrogen and phosphorus content.

Perhaps the most important information shown in Table VIII concerns the content of grease. A significant increase occurred in the grease content of the sludge from each digester as the detention period was decreased, with 9.5 per cent grease in the sludge from the 6-day digester or nearly 50 per cent more grease than in the 20-day sludge.

Discussion of Results

It should be pointed out that the results obtained in these laboratory studies probably are somewhat more favorable than would be expected in plant practice. The principal reason for this condition is that the laboratory digesters were not fed on a strict displacement basis (wherein part of the freshly added sewage solids would have been included with the sludge displaced during feeding).

By the techniques used in these studies, all solids added to the digestion units were subjected to at least 12 hr. of anaerobic contact before having an opportunity to escape from

TABLE VIII.—Fertilizing Values of Digested Sludge[1]

Item	Digester Detention Period, Days				
	6	8	10	15	20
Positive					
Nitrogen, as NH_3 (%)	2.92	3.03	3.02	3.07	3.07
Phosphorus, as P_2O_5 (%)	1.82	2.04	2.07	2.09	2.10
Negative					
Grease (%)	9.50	8.85	8.05	7.15	6.65

[1] Based on a 75-day period; average of four samples.

the digester. Morgan (8) has shown that a considerable proportion of the total potential gas from sewage sludge is generated during the first 12 hr. after feeding. Thus, the results obtained are probably more representative of those that would be obtained where operational procedures are controlled to limit losses of freshly added solids by short circuiting.

High-rate sewage sludge digestion units can be expected to operate either using highly dewatered sludge or thickened sludges as proposed by Torpey (3), or using regular sludges with post-dewatering as proposed by Morgan (8). There are definite advantages to each method, and undoubtedly the manner of ultimate sludge disposal will determine to a considerable degree the method selected. Feeding of thickened sludges allows greater organic loadings or longer detention periods, whichever seems best engineering practice. Up to the present time, it does not appear that excessive organic loadings can be applied to a digester while still maintaining reasonable detention periods. The limiting factor appears to be related to present inability to thicken sludge adequately, or pump sludge which is highly concentrated.

Dewatering of sewage sludges prior to digestion has one disadvantage in that all the non-volatile biochemical products of decomposition remain in the digested sludge mass. The principal item of concern is the content of ammonium and other salts which may be represented by alkalinity. Figure 4, from the report by Schmidt (5), shows the alkalinity of digested sludge will increase in direct proportion to the solids content of the sludge fed to a digester. If vacuum filtration of digested sludge is practiced, this item alone can make elutriation mandatory and, undoubtedly, somewhat more difficult.

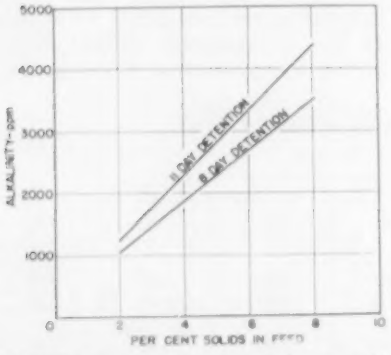

FIGURE 4.—Alkalinity in relation to solids concentration and detention time.

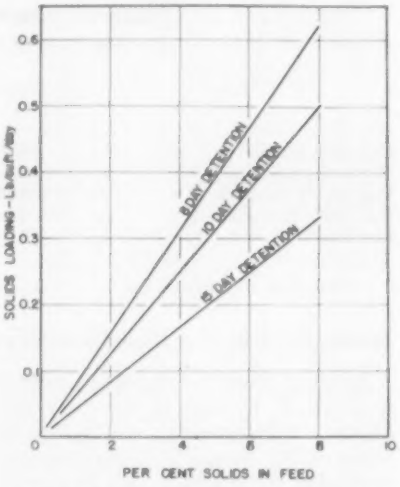

FIGURE 5.—Solids loading as a function of solids in the feed sludge and the detention period.

In view of information which exists at the present time, it appears that high-rate digestion units can be operated safely using a 10-day detention period, without significant sacrifice of gas production or degradation of sludge quality. The solids loadings which may be applied will be a direct function of the solids content of the sludge fed to the unit as shown in Figure 5. By using a 10-day detention period and by feeding an 8 per cent sludge, the total and volatile solids loadings will approximate 0.5 and 0.35 lb. per cubic foot per day, approxi-

mately 7 times the conventional rate of feed.

The importance of adequate mixing to maintain a mixed liquor condition is to be emphasized. The principal reason is to maintain the fresh solids in intimate contact with active biological forms, and in a proper environment for normal decomposition at all times. This simply means that segregation of solids in a scum layer cannot be tolerated if maximum digester efficiency is to be obtained. As solids loadings are increased or detention periods are decreased, the tendency for scum formation increases. This tendency is cancelled in some degree by the more rapid evolution of gas which occurs under such conditions, but gas evolution cannot be depended upon to control the scum problem. Supplementary mixing is mandatory and must be continuous. Heavy scum formations will occur in a matter of a few hours if mixing is interrupted.

Summary

1. A series of laboratory sewage sludge digestion units were operated successfully for a period of 77 days at detention times of 6, 8, 10, 15 and 20 days. The digesters were fed twice daily and the contents were mixed continuously by recirculation of gas. Volatile solids loadings were greatest in the 6-day digester, and ranged from 0.26 to 0.38 lb. per cubic foot per day.

2. Volatile matter destruction varied from 52.2 per cent in the 6-day digester to 58.2 per cent in the 20-day digester, while grease destruction was 53.0 and 71.4 per cent, respectively.

3. Gas yield decreased in proportion to the volatile matter destroyed. The decrease was practically all related to methane; yield from the 6-day digester was 88.8 per cent of that from the 20-day unit.

4. Gas yield per pound of volatile solids destroyed varied from 16.5 to 17.1 cu. ft., with no definite relationship to detention time.

5. Ammonia nitrogen determinations on the digested sludge indicated that protein degradation in the 6-day digester was 86 per cent of that in the 20-day unit.

6. The nitrogen and phosphorus content of all digested sludges was quite uniform, except in the digested sludge from the 6-day unit where it was noticeably lower.

7. The grease content of the digested sludge increased significantly as the digestion time decreased, ranging from 6.65 per cent in sludge from the 20-day digester to 9.50 per cent in sludge from the 6-day unit.

Acknowledgment

The information presented represents control data obtained during an investigation on the "Survival of Pathogenic Organisms during High-Rate Sludge Digestion" and was supported by a grant from the National Institutes of Health, U. S. Public Health Service.

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Industrial Wastes

FULL-SCALE MODIFIED DIGESTION OF MEAT PACKING WASTES *

By Alfred J. Steffen

Sanitary Engineer, Research and Technical Department, Wilson & Co., Inc., Chicago, Ill.

The first full-scale modified digestion facility to treat meat processing wastes will be constructed at Albert Lea, Minn. for Wilson & Co. This waste treatment plant incorporates a number of new features. Its design is based in a large part on the studies conducted on a pilot-scale plant at Austin, Minn. by Geo. A. Hormel & Co. with the cooperation of the American Meat Institute.

Research

The first studies on the anaerobic digestion of meat packing wastes were undertaken in 1948 on a barrel-scale basis at Austin, Minn. (1). Until then anaerobic digestion had been limited to the treatment of sewage sludge and certain high B.O.D. wastes, particularly wastes from fermentation industries. In the earlier studies, it was found that packing plant wastes ranging from 800 to 1,800 p.p.m. B.O.D. could be successfully treated by anaerobic digestion. The research showed that the relatively high temperature of packing plant wastes (82° F. to 85° F.) and the high volatile solids content (1,200 to 3,000 p.p.m.) were distinct advantages in the anaerobic process.

A large-scale pilot plant with a 940 cu. ft. digester was built in 1951. A barrel-scale digestion plant was also operated at the Wilson & Co. plant at Albert Lea, Minn. to study the process under local conditions. Digestion was successful, but difficulties were encountered in clarification of the digester effluent. This process is comparable to the activated sludge process in that the floc, which is made up of organisms and entrained and agglomerated organic material, must be separated from the process liquor not only to obtain a suitably treated effluent, but also to return floc to the process as seed. However, the gases entrained in the floc caused extreme variations in settling performance. Sometimes the floc settled successfully, sometimes it floated and sometimes it merely moved up and down in the liquor, depending on the loading on the process, volatile acid concentration, solids concentration and a number of other factors.

In 1952, the Committee on Meat Packing Plant Waste Disposal of the American Meat Institute became interested in this method of waste treatment and engaged research engineers to evaluate the process and suggest further research. The possibilities of improving sludge separation by degasification were investigated (2). Vacuum degasification at about 20-in. of vacuum proved successful, using a baffled cascade arrangement in an elevated degasifier.

Further studies were made on the mixing in the digester, the loadings in terms of B.O.D. and volatile solids,

* Presented at 1955 Annual Meeting, Central States Sewage and Industrial Wastes Assn.; Rochester, Minn.; June 22–24, 1955.

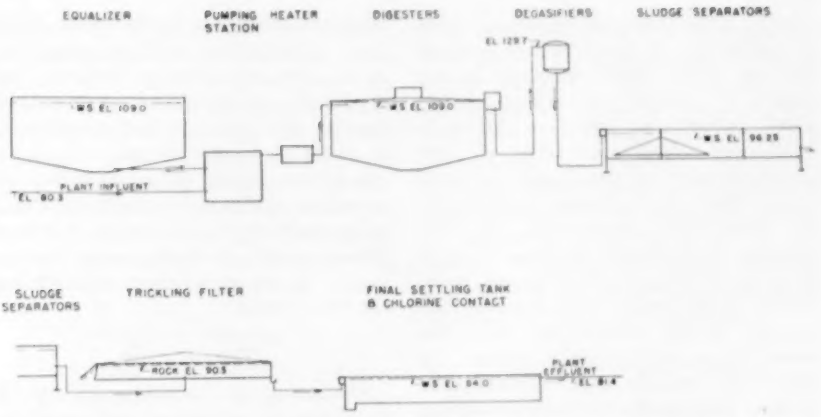

FIGURE 1.—Hydraulic profile of the meat processing waste treatment plant for Wilson & Co., Inc., at Albert Lea, Minn.

the treatment of packing plant wastes in lower B.O.D. ranges, the effect of temperature variation and on other variables which can influence the process. It was shown that typical packing plant wastes can be successfully treated after a 12-hr. digestion period, with loadings of 0.22 lb. of B.O.D. per cubic foot of digester capacity per day and a digestion temperature of 95° F. Removals of B.O.D. were 95 per cent and suspended solids removals were 97 per cent. Good mixing in the digester and high solids concentration in the mixed liquor were essential features of the process.

Design Approach

Evaluation of this process for full-scale development revealed that an anaerobic digestion plant for treating packing plant wastes can be built for approximately two-thirds the cost of a conventional two-stage trickling filter plant. Operating costs are slightly higher than for a trickling filter plant because of power requirements in mixing and degasification. Some auxiliary fuel is also necessary when the total volatile solids content in the waste is too low to yield the gas required for digester heat or when the temperature of the incoming waste is lower than normal.

Analytical data on the wastes from the packing plant at Albert Lea have been collected over a period of several years and daily flow and temperature records have been collected continuously during the past year. These data have been evaluated to obtain the basis for the design.

Figure 1 shows the hydraulic profile of the proposed plant to be built by Wilson & Co. The 20 in. of vacuum drawn in the degasifiers results in a relatively steep hydraulic gradient.

Table I gives the unit loadings on which the design was based.

As the design progressed the usual difficulties in translating pilot-scale

TABLE I.—Waste Treatment Plant Design Criteria, Wilson & Co., Inc., Albert Lea, Minn.

Unit	Design Basis
Equalizing Tank	100 per cent equalization = 27 per cent of total flow
Heaters (2)	Maintain digesters at 95° F.
Digesters (2)	0.15 lb. B.O.D./cu. ft./day 0.15 lb. volatile solids/cu. ft./day
Degasifiers (2)	Remove all of the methane and most of the CO_2. Design for 20-in. vacuum
Separators (2)	1 : 1 to 3 : 1 sludge return at 600 g.p.m./sq. ft., surface rate
Trickling Filter	Loading 23 m.g.a.d 2,600 lb. B.O.D./acre ft.
Final Clarifiers (2)	800 gal./sq. ft./day

results into full-scale practice were encountered. It soon became evident that the plant should be built in two stages, to provide an opportunity to make operating tests on full-scale equipment. The first stage of construction will be essentially one-half of the final plant as shown in Figure 2. This stage construction is quite common in industry because it permits the investigation of a new process on a full-scale single unit of the process before proceeding with the construction of the entire plant. In municipal practice stage construction is rare principally because municipal financing does not lend itself to this type of procedure.

Flow Equalization

The pilot-scale studies indicate that this process will operate successfully with some fluctuations in flow. However, equalization of flow seems necessary for conservative design. Accordingly, an equalizing tank providing for 100 per cent flow equalization is included in the design. To determine the degree of equalization required it is planned to omit the equalizing tank in the first stage but both digesters will be built, using one digester as an equalizing tank during the test period.

Temperature

Designing to maintain 95° F. in the digesters presented some problems. After many alternatives were studied, it was decided to heat the digesters by pumping the incoming raw waste through external heat exchangers. Piping also is provided to divert return sludge through the heaters dur-

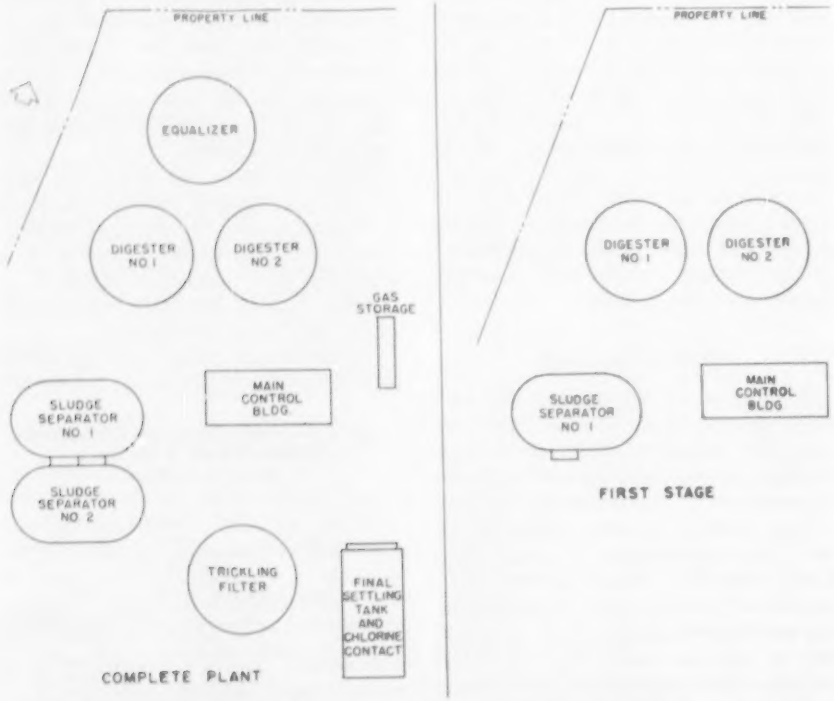

FIGURE 2.—Unit diagram showing the stage planning of the Wilson & Co., Inc., waste treatment plant.

ing periods of low flows. The heaters are equipped to burn digester gas, natural gas, or oil. Provisions are made in the second stage of the construction for the storage of digester gas under pressure. Evaluation of information obtained in studies on the first stage facilities will improve the knowledge concerning gas fluctuations so that gas storage requirements can be determined more definitely.

Digester Mixing

It is common knowledge that mixing improves digestion and the pilot studies further emphasized the importance of adequate mixing in this process. In the pilot-scale studies mixing is accomplished by recirculating the digester contents from the bottom of the digester to a splash plate above the liquid surface of the digester at a rate of about 40 to 50 turnovers per day. Since this type of mixing is not feasible on a large scale, possibilities of mechanical stirring and gas mixing were studied. Experimental information on mixing could not be directly translated to the full-scale plant because the pilot-scale digester is not a prototype of the digesters in this design. However, subsidence characteristics of the floc were studied.* These studies were followed by studies of turbine mixing on a prototype unit to demonstrate the feasibility of turbine mixing. Gas mixing has also been studied at Austin. An open turbine mixer will be installed in the first-stage plant, although gas mixing can be installed later.

Degasifiers

This is believed to be the first waste treatment plant incorporating degasifiers in the treatment process. The design of these units was based on the feed-water deaerators commonly used in steam generating plants. The degasifiers will consist of two vertical steel tanks, each 11 ft. in diameter and 9 ft. deep. The effluent from each digester will be pulled into the particular degasifier under a 20-in. vacuum produced by vacuum pumps installed in the control building. The liquor will splash down on a series of slats to aid release of the gases which will be exhausted from the top of the degasifier by the vacuum pumps. The degasifiers will be insulated and mounted on supports over the digesters.

Separation of Solids

The separation of return sludge from the digester effluent is an interesting problem. The sludge is exceptionally light and does not respond to the plowing action of customary sludge scraper mechanisms. Large sludge volumes are involved since the sludge concentration is four to six times that of a typical activated sludge. In the pilot studies separation was achieved with equipment that removed the sludge through suction nozzles which moved slowly along the tank floor. The separators will also be of this type and will consist of dumbbell-shaped tanks each equipped with two circular sludge removal mechanisms. Sludge return rates will range from one to three times the equalized raw flow, a much greater return rate than is normal for activated sludge. This high rate, coupled with extremely low flows during week ends, results in a ten-fold range of flow through the suction nozzles. To provide for this wide range of return sludge rates, a swinging pipe will be provided to withdraw sludge from the receiving sump at variable rates. This will allow full use of the 9-ft. depth of the settling tank for head in regulating the flow from the sludge removal equipment. If studies during the first stage of operation show that the return sludge rate can be reduced, it is possible that telescopic valves will be substituted for the swinging pipes in the subsequent separator construction.

* Sponsored by the American Meat Institute, University of Minnesota.

One of the advantages of the anaerobic process is the high concentration of suspended floc that can be carried in the biological part of the process. However, these concentrations, which range from 1.1 to 1.6 per cent suspended solids, present some problems in sedimentation. Recent studies reveal some advantages in two-stage settling for successful and economical solids removal. If experience gained in the first stage of the operation studies substantiates these laboratory findings, two stage settling can be incorporated in the final design.

Disposal of Excess Sludge

Excess sludge will be concentrated in a small concentrating tank and then discharged into two lagoons with a total capacity of 470,000 cu. ft. Provisions will be made for returning the surface liquor or sludge from the lagoons to the digestion process. Possible use of the excess sludge for feed or fertilizer supplements will be explored later.

Final Treatment

The design provides for aerobic treatment as the final treatment step. This will be accomplished in a single-pass high-rate trickling filter followed by final clarifiers and chlorination for sterilization of the effluent. Experiments at the pilot plant with a trickling filter 8-ft. in diameter by 4.75-ft. in depth gave B.O.D. removals equal to at least two-thirds of the removal expected in treating domestic sewage after primary sedimentation. The aerobic stage of this plant will be built after the initial studies are completed.

Acknowledgments

Stepping from pilot scale to full scale in any process necessitates a close working relationship between research engineers, design engineers and equipment manufacturers. The completed design is a composite resulting from the unselfish cooperation of many individuals. We look forward to their continued help in the studies that lie ahead.

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PAPER INDUSTRY REPORTS ON WASTE TREATMENT PLANT CONSTRUCTION

The 1954 Annual Report of the National Council for Stream Improvement estimates that the pulp, paper, and paperboard industry has expended in the neighborhood of $70,000,000 for waste treatment plant construction over the past 10 years. This estimate is based on a recent survey of 329 mills by the National Council staff, indicating that 55 per cent of the mills in the survey had installed waste treatment facilities.

Five years ago a survey by the National Association of Manufacturers on water usage and waste treatment in industry showed that 37 per cent of all paper mills in the United States had waste treatment plants. These figures indicate an accelerated rate of treatment plant construction by the paper industry.

FUNDAMENTALS OF THE CONTROL AND TREATMENT OF DAIRY WASTE*

By H. A. Trebler and H. G. Harding

Respectively, Chemical Engineer, Consultant to Milk Industry Foundation, Washington, D. C., and Senior Scientist, National Dairy Research Laboratories, Inc., Oakdale, Long Island, N. Y.

The function of the dairy industry in the United States is to collect more than 120 billion pounds of milk per year from nearly four million dairy farms, process it and distribute the milk and dairy products to 160 million ultimate consumers in a sanitary and economical manner, and with a minimum of spoilage and waste. The particular difficulties of the industry are closely related to the wide distribution of the raw materials which make it necessary to have more than 30,000 plants, many of them small; the perishable nature of the products; the wide seasonal fluctuation in production; the high sanitary requirements; and the great variety of products. Fortunately the trend is to larger plants, more handling of milk and fluid dairy products in tank trucks instead of 10-gal. cans, and less wasteful equipment.

As with all industries having strong organic wastes, rigorous waste saving and utilization of by-products are of the utmost importance. Progress in this direction has done much more to reduce stream pollution caused by dairy waste than all the dairy waste treatment plants that have been built or will be built. It will always be cheaper to keep waste out of the sewer than to put it in and then remove it with expensive waste treatment methods.

Waste saving and prevention methods have been described in a number of papers and in manuals issued by various individuals and agencies (4) (24) (25) (32). Where dairy plant management and operating personnel appreciate the desirability of waste saving, considerable reduction in floor waste volume and strength has resulted (28) (18) (8).

Separation of Wastes

The reduction of the volume and strength of floor wastes to a practical minimum will reduce the size, installation cost and operating cost of the waste disposal facilities. One important step is the elimination of steam-water mixing tees for making hot water and the use of a regular hot water system. This allows the use of shut-off valves at the end of the hose lines which has resulted in a 40 to 60 per cent reduction in floor waste volume in small receiving stations.

Separation of strong wastes, wash waters, clean cooling waters and sanitary wastes (12) is indicated in almost all cases except where irrigation is used as the method of treatment. If practical, sanitary wastes should be discharged to sewers or to a separate septic tank and drain field.

It is particularly important that the sulfuric acid used in butterfat testing should not be dumped into the sewer. The acid should be dumped separately in a cinder pile or other suitable location. Another special waste that causes trouble when discharged to the

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sewer is the strong caustic solution from bottle washers or from cleaning evaporating equipment. The best method of disposal is by reusing the caustic after separating the suspended matter. Where this is not possible, the caustic solution should be dumped separately in some place where it will not cause a nuisance. If the caustic must be discharged to a sewer it should be distributed sufficiently so there will be no pronounced change in the pH of the waste.

By-products Utilization

Formerly the skim milk from the separation of milk and cream, the buttermilk from churning cream, and the whey from cheese manufacture were by-products whose utility and value were so low, especially during the seasonal flush, that they were discharged to the sanitary sewers. These by-products have such a high B.O.D. that it is not practical to treat them by biological oxidation even when mixed with cooling waters and floor wastes. By-product utilization (33) is the preferred method of disposal even when the products have to be sold without profit.

Fortunately the nutritive value of these by-products is high and there is a growing market for them as human and animal foods. The lactose (milk sugar) in whey can be removed by yeast fermentation or can be converted to simpler sugars by enzymes (23). The resulting whey solids can be used to make up a much larger proportion of the animal diet.

Lactose has a limited market, mainly in infant foods, media for making penicillin and certain pharmaceutical preparations. It may be fermented to lactic acid or converted into various metallic lactates. At present the market for these chemicals is limited.

Whey can be fermented to butyl alcohol, acetone and ethyl alcohol. The latter may be converted to vinegar.

Industrial uses for domestic casein, made by the acid coagulation of skim milk, have been, in large part, displaced by cheaper grades of imported material. New applications for edible grades of domestic casein in human foods show promise.

The dairy industry, and state and government laboratories are searching for new products with a large potential use that can be made from dairy by-products. As yet, the best use appears to be as food for man and animals.

In order to concentrate and process by-products economically, a considerable volume of fluid milk must be available at one location. This makes it particularly difficult for the large number of small dairies whose flush volume is not great enough to justify special handling equipment for by-products. Fortunately, there continues to be a trend towards larger plants which will handle the surplus milk and by-products from neighboring small dairies. But many small dairies are located so far from the nearest large plant that transportation of surplus by-products is not economical. For these plants the best immediate solution to the by-products problem has appeared to be dumping on isolated land where odor nuisance is not a problem and where there is no runoff to a stream.

Floor Waste Composition

Dairy products contain butterfat, milk sugar and milk protein in varying proportions (Table I). These relative proportions in the waste vary according to what the plants do with the milk after receiving it. For instance, in a milk receiving station that only weighs and cools the milk the waste is essentially diluted milk. The same thing applies to a plant that makes plain evaporated milk. However, if a plant makes butter or cheese the proportions of the original milk ingredients tend to be distorted in the waste and this may have some bearing on the treatment of the waste from these plants.

TABLE I.—Approximate Average Composition of Milk and Dairy Products [1]

Product	Butter-fat (%)	Protein (%)	Lactose (%)	Total Solids (%)	Organic Solids (%)	B.O.D. (%)	Pop. Equiv. per 100 lb.
Whole milk	3.9	3.2	5.1	12.9	12.2	10.3	61
Evap. milk	7.9	6.7	10.0	25.9	24.5	20.8	125
Skim milk	0.1	3.3	5.3	9.5	8.7	7.2	43
Dry skim milk	0.9	36.9	50.5	96.7	88.6	73.7	442
Sweetened skim, cond. milk [2]	0.3	10.4	16.8	70.0	67.5	50.2	301
Buttermilk [3]	0.4	3.4	4.3	9.4	8.7	7.2	43
Whey [4]	0.3	0.9	4.9	6.9	6.3	3.5	21
Cheddar cheese	35.5	26.6	1.5	76.5	73.0	60.0	360
Cream	40.0	2.2	3.0	45.6	45.2	39.9	239
Ice cream mix [5]	12.0	3.9	5.9	37.7	36.9	29.2	175

[1] Averages from various sources.
[2] Also contains 40 per cent sucrose.
[3] Ripened cream buttermilk with 0.6 per cent acidity.
[4] American cheese whey with 0.2 per cent acidity as lactic acid.
[5] Also contains 15 per cent sucrose.

In addition to dairy products, the wastes also contain significant amounts of cleaning and sanitizing compounds and miscellaneous soils from the washing of containers and floors.

The fundamentals of dairy waste treatment are not different from the fundamentals of treatment of any other organic waste of similar composition and concentration. Most foods wastes, even municipal wastes, contain fats, carbohydrates and proteins in varying proportions. From a microbiological or waste disposal point of view it does not make much difference whether the waste constituents come from milk or other animal or vegetable origin.

At one time dairy wastes were considered difficult to treat with available methods and consulting engineers would advise against accepting dairy wastes in municipal treatment plants. Gradually it became apparent that dairy wastes are actually about the easiest wastes to treat by biological methods since milk and milk products are Nature's most perfect foods both for man and for a large number of animals and microorganisms. The important facts are simply that dairy wastes usually are strong and due to their excellent nutritional properties they are rapidly oxidized by various organisms and consequently require rapid and ample oxidizing capacities. Furthermore, in fresh wastes a large part of the B.O.D. is present in soluble form so that relatively little B.O.D. reduction can be expected by primary sedimentation unless the proteins are first coagulated.

If the above facts are taken into consideration, dairy wastes can be treated successfully with any one of the existing biological methods and in any municipal sewage treatment plant that has sufficient secondary treatment capacity.

Pre-treatment

All floor wastes should pass through a simple combination sand trap, fat trap, screen tank, and measuring and sampling weir tank (Figure 1). This is highly desirable for all plants regardless of disposal method, even if the waste is discharged to a large stream or a municipal sewer. It is particularly important when the waste is pumped through high-pressure pumps, as in spray irrigation.

Most dairy wastes do not carry any important quantity of fat; however,

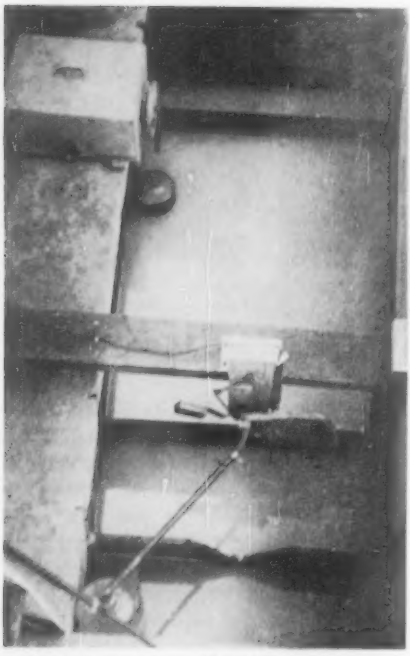

FIGURE 1.—Combination sand trap, fat skimming and flow measurement and sampling weir tank.

some cheese plants will lose cheese curd containing fat, some of which tends to float. Also, pasteurizing plants that bottle milk in paper containers may lose considerable paraffin wax to the sewer. In these plants it is advantageous to build the pre-treatment tank rather long and place a skimming bafflle just ahead of the screens (or the sampler if one is used) in order to keep fat and floating matter away from them. The tank should be skimmed once a day and the skimmings burned or buried together with the screenings.

The combined grit, screen and skimmining tank should be at least 30 in. deep. For good fat separation the surface area of the tank should be 20 sq. ft. per 1,000 gal. at maximum hourly flow, the tank being about twice as long as it is wide. The width should be at least 30-in. for ease of grit removal from the tank bottom and to facilitate installing an automatic sampler. To facilitate cleaning, the perforated metal screen, with $\frac{3}{8}$-in. perforations and maximum open area, should be placed on a 60° angle with the horizontal and be bent over at the top to form a convenient shelf for the accumulation and draining of solids. For grit removal the tank should provide about 10 min. retention at maximum flow. Consequently, a tank $2\frac{1}{2}$ ft. $\times$ $2\frac{1}{2}$ ft. $\times$ 8 ft. would in most cases be ample for both grit, fat and wax removal for a 1,000 gal. per hour flow. The tank should be placed conveniently, preferably inside a pump house or other building with good light and a water hose for ease of cleaning. Where the tank bottom is more than 3 ft. underground, because of a low sewer level, there should be a service platform along one side of the tank at the 3-ft. level.

Flow Measurement and Sampling

Proper flow measurement, sampling and testing are important for checking and improving waste saving performance, for obtaining design data for new treatment facilities and for checking the performance of existing treat-

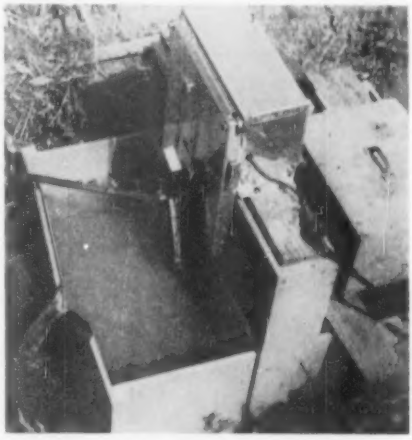

FIGURE 2.—Portable weir tank with a continuous automatic sampler and a water-level recorder.

ment facilities. The continuous automatic scoop sampler (Figure 2) (25) (27) takes samples at regular time intervals in proportion to the flow.

After considerable waste survey work had been done in a great number of dairy plants, a table of "standard losses" was published in 1947 (29). The standard loss or standard milk process loss is the pounds of B.O.D. per 10,000 lb. of milk or milk equivalent which can be expected in the floor wastes from each process in a dairy with reasonably modern equipment and careful operation. This loss table has been reprinted in various manuals and used widely as an aid in reducing waste. It even has been used as a basis for the design of treatment facilities, a use for which it may not be too well suited, since with up-to-date equipment all plants should be able to do much better with waste saving than what is indicated in the table. The table was revised in 1949 (31) and reprinted in a manual in 1950 (32) but even this is now out of date. For instance the "standard loss" for receiving milk in 1947 was estimated at 7 lb. of B.O.D. for each 10,000 lb. of milk received. In 1949 this was revised to 4 lb. In 1954, tests at one large receiving station in New York State showed less than one pound of B.O.D. per 10,000 lb. of milk and tests at two receiving stations in Pennsylvania showed less than 1.4 lb. of B.O.D. per 10,000 lb. of milk intake. Plants that can consistently reduce their losses to this extent presumably will never need any treatment facilities except possibly a grit and screen tank with facilities for flow measurement and sampling.

There are large fluctuations in waste volumes and organic loads both seasonally and from hour to hour during the day in the same plant (28) (29) (34). Even from day to day in the same plant different products are often made and as a result the waste varies. Therefore, it is most important, when sampling a plant for the purpose of designing waste disposal facilities, that the survey be conducted during a sufficient number of days to get a correct picture of the volume and load situation. It is also important to conduct the survey during the time of the year when the waste load is greatest or to adjust the design to the calculated average load for the 10 consecutive days with maximum milk intake or maximum calculated load. Because of these great fluctuations in the load from dairy manufacturing plants, it is desirable to have a somewhat flexible waste disposal setup. This may mean having some extra tank and aeration capacity available for the flush season. The rest of the year this capacity would serve simply as standby equipment.

Discharge to Municipal Sewers

Wherever possible and when a fair agreement can be reached with the municipality, the preferred method of disposal of dairy wastes is to the public sewer. There are no particular technical difficulties in treating dairy wastes in municipal sewage treatment plants provided sufficient oxidizing capacity is available and can be supplied at a high enough rate. Where the municipal plant has only primary treatment, the dairy waste should be pre-treated by aeration with sufficient air to maintain aerobic conditions for approximately four hours in order to remove lactose. It should not be necessary to use a settling tank or return sludge system in this case as the aeration tank will maintain its own flora partly as a free dispersed growth of microorganisms and partly as visible floc. If the municipal treatment plant has both primary and secondary treatment, removal of lactose at the dairy is not needed. However, if the dairy waste is very strong it may sometimes be desirable for the municipal plant to increase the rate of pumping sludge from the bottom of the secondary clari-

fier back to the influent end of the primary clarifier in order to help push the milk waste through the primary and into the secondary aerobic treatment unit. If much dairy waste remains in the primary settling tank for any length of time, lactic acid may be formed and the pH may decrease, causing trouble in settling and the subsequent digestion of the sludge.

By-products such as whey, buttermilk and skim milk should not be discharged to a municipal sewage treatment plant unless considerable dilution is available. If these products are discharged accidentally the treatment plant personnel should be notified so that precautions can be taken, preferably by increasing recirculation ratios if the plant is equipped to do this.

Some municipal plants with activated sludge treatment or trickling filters seem to be able to handle large amounts of these strong by-products without difficulty. These particular plants usually have considerable excess oxidizing capacity or at least they have high recirculation ratios.

Another interesting method (1) (2) for disposing of relatively large quantities of excess by-products consists of hauling in tank trucks to the municipal disposal plant. The excess whey and other products are fed directly to the sludge digester with no harmful effect on the digestion process and a large increase in gas production.

Aerobic Treatment

Streams, Lakes and Ponds

Where it is not possible to discharge dairy waste to a municipal sewer at a reasonable cost, the most economical method of disposing of the floor waste appears to be by pretreatment as discussed above and then by natural biological oxidation in streams or lakes where permissible and where sufficient dilution is available.

In some cases a shallow pond may be available or can be constructed inexpensively. These ponds will handle only about 45 lb. of B.O.D. per acre per day without deteriorating into septic lagoons (9). Consequently quite large ponds would be required to handle the waste from even a medium-sized dairy plant.

Irrigation

By means of ridge and furrow irrigation, settled sewage can be applied to land at the rate of 3,600 to 30,000 gal. per acre per day, depending on the soil conditions (13). Work on canning plant waste (3) indicates that the settled waste volume and not the B.O.D. is the controlling factor since B.O.D. loadings of 649 and 5,660 lb. per acre per day and volumes of 134,000 and 96,000 gal. per acre per day are reported for Iowa soil during the four-week canning season. Under certain conditions, where suitable level land is available near the dairy plant, this may be an economical method of treatment. Apparently freezing in the winter does not create trouble because the long grass protects the furrows from the cold.

Recently much interest has been shown in spray irrigation for both dairy waste and canning waste (5) (19). Many different spray systems and cover crops are being tried. While definite data are still lacking it appears that the loadings per acre can be many times those for oxidation ponds. Freezing in winter may be a problem if the pipes are laid on top of the ground. The method certainly seems ideally suited to pastures and field crops in relatively dry areas where both the irrigation and the fertilizer value of the waste can be beneficial. The disposal of concentrated by-products, such as whey or buttermilk, is more difficult with spray irrigation unless considerable dilution and/or large areas are available.

Recently some interesting experiences have been reported (15) with spraying vegetable and fruit packing

wastes in wooded areas with extremely high loadings per acre both in terms of volume and organic material. There is no reason to believe that dairy wastes cannot be treated in a similar manner.

In all of these methods and especially where high pressure pumps have to be used, it is essential for trouble-free operation that proper pretreatment for grit, fat and large solids removal be provided ahead of the pump. Also the selection of a suitable submerged pump is highly desirable. The installation of pumps in dry wells adjoining the pump pit is expensive and impractical for small plants. If winter operation is required the feeder lines to the sprays must be installed underground or drained at the end of each day's use. The screen pit, pumps and appurtenances must be properly housed or otherwise protected against freezing.

Sand Filtration

Another method of biological oxidation is by intermittent filtration on sand beds. Again, it is essential that coarse suspended matter be removed ahead of the beds. Good sand beds are quite expensive to install and maintain and the permissible loading per acre is quite low, 50 to 100 lb. of B.O.D. per acre per day and 50,000 to 120,000 gal. per acre per day (13). This method probably is not being used any more for direct treatment of dairy wastes although it still may be used for polishing effluents from trickling filters.

Trickling Filters

Various types of trickling filter installations have been found satisfactory for the treatment of dairy wastes. Following the practice in municipal waste treatment, the earlier trickling filters were the "low-rate" type fed periodically by gravity from a syphon tank or by a float-operated pump. It was soon learned that if strong organic wastes were to be treated by this method they had to be diluted either with cooling water or with trickling filter effluent so the influent B.O.D. to the filter approached that of sanitary waste (200 to 300 p.p.m.). Even so, considerable ponding and filter fly difficulties were encountered. However, the high-rate recirculating trickling filter is much better suited for strong organic wastes. Larger pumps and more power are required but the additional operating expense seems

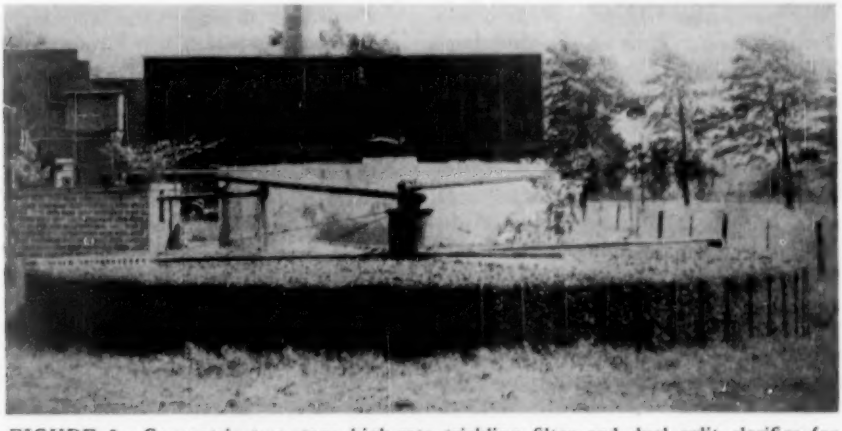

FIGURE 3.—Concentric two-stage high-rate trickling filter and dual split clarifier for treating dairy wastes.

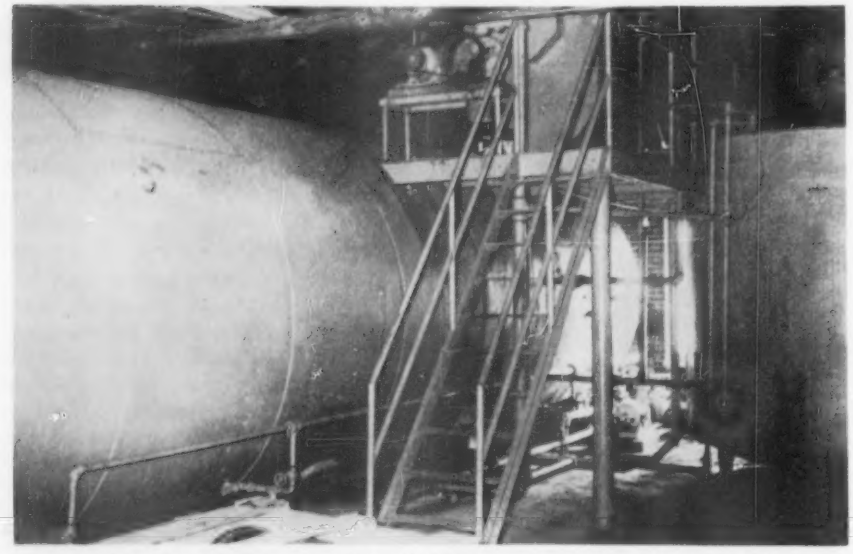

FIGURE 4.—Horizontal and vertical cylindrical aeration tanks, with a total of 8 tangential No. 4 air eductors placed 1 ft. above the tank bottom, supplied with recirculated mix liquor at 15 p.s.i. and 50 c.f.m. of air at 4 p.s.i. Rated capacity is 50 lb. of B.O.D. per day. Tanks also serve to equalize the flow.

well justified by the improved performance and relative freedom from filter fly and ponding troubles.

With the high average ratios of recirculation (5:1 to 10:1) that have to be used in order to get the high rate of flow (more than 15 m.g.a.d.), it is doubtful if two-stage treatment is of any particular benefit. With a concentric arrangement of the two stages of the trickling filter (Figure 3) and with a split clarifier (26) for the two stages of settling, the difference in cost is small and the added security against raw waste short-circuiting might well be worth this added cost.

A certain amount of sludge is produced by the sloughing of biological material from the filters and this sludge can be disposed of either in a digester or on drying beds. This type of sludge seems to dry well on open sand beds without causing any nuisance.

In Great Britain and other countries of the British Commonwealth (22) alternating two-stage trickling filters are preferred because better final effluents (10 p.p.m. B.O.D.) are obtained for the same average B.O.D. loading (0.5 lb.) per cubic yard of total trickling filter medium. Less power is used, sludge volume is less and ponding is prevented.

According to experience the high-rate trickling filters will produce almost as good effluents when used with the same low loadings (0.5 lb. B.O.D. per cubic yard). Under most conditions operation is quite satisfactory with considerably higher loadings (1 to 3 lb. B.O.D. per cubic yard), but there is some sacrifice in effluent quality. The advantages of the high-rate trickling filters are undoubtedly their relative freedom from odor and filter fly problems when properly maintained and not consistently overloaded. The part of the effluent that is recirculated in a high-rate system actually needs no clarification or only partial clarification (30).

Aeration Tanks

Tank aeration in a great variety of arrangements, with or without provisions for inoculation of the incoming waste with return sludge, is being used more or less successfully for treating all kinds of dairy wastes.

Aeration tanks built of reinforced concrete, concrete block, wood or steel and located underground or above ground are in successful operation. The tanks can be square, rectangular, or horizontal or vertical cylinders and can be insulated or installed inside a new or existing building (Figure 4). The tanks can be deep or shallow and can have a constant liquid level. They also may be operated as a combination aeration and flow equalizing tank with variable liquid level or even as batch treatment tanks.

Important requirements for aeration tanks appear to be:

1. Sufficient tank capacity to handle the waste. This may mean as little as one-eighth to one-quarter of the daily waste volume with straight activated sludge type of operation and as much as double the daily waste volume for batch operation with maximum aerobic sludge digestion.

2. The tank shape should facilitate good agitation to obtain optimum contact between the oxygen, organic material and microorganisms, and to avoid settling in stagnant corners.

3. Ample freeboard to take care of occasional foaming.

4. The tank should be installed to facilitate maintenance of as high a temperature as practical (to 90° F.) by either housing or installation underground. Covering will also prevent the entry of leaves or other foreign matter which may cause clogging of pumps or jets.

Oxidation Requirements

In regard to aeration devices, it is not certain that it is necessary at all times to have dissolved oxygen present as measured by the usual test. Since there is a time lag between sampling and testing in both the dissolved oxygen test and the Redox test, it appears that aerobic conditions may be maintained even when for several hours the tests may indicate a lack of oxidizing capacity.

The actual quantity of air required per pound of B.O.D. in the raw waste is relatively unimportant. It is the oxidizing capacity of the air that counts. This depends on a number of factors such as temperature, degree of agitation, amount of sludge, surface area of air bubbles and the time of contact of the bubbles with the liquid. In addition, it appears that a certain degree of breakup of the floc is desirable for rapid oxidation but that too much breakup is harmful and conducive to foaming and sludge bulking. Consequently, the selection of the aeration device is important in order to get maximum oxidation per horsepower (rather than per cubic foot of air) and a minimum of foaming and bulking.

Experiments with synthetic dairy waste (1,000 p.p.m. sludge plus 1,125 p.p.m. C.O.D. from skim milk) (17) showed that at 68° F. a good active sludge removed more than 89 per cent of the C.O.D. from the solution within three hours. Apparently about 18 per cent was converted into new cell protoplasm, 60 per cent stored in the sludge and 11 per cent actually oxidized to carbon dioxide and water. The part of the C.O.D. that was stored in the sludge was then oxidized more gradually at a lower rate and after 20 hr. more than 20 per cent still remained in storage and 41 per cent was in the form of new cells. The total oxygen requirement of the system is the sum of the immediate requirement of the raw waste plus the requirement of the endogenous oxidation of the cells themselves.

This modifies the earlier statements by the same group of investigators

(14) (16) that dissolved oxygen must be provided at an extremely high rate at the time raw waste enters the aeration tank. The practical experience of many workers in this field indicates that even in plants where the raw waste load enters with extreme nonuniformity, satisfactory performance is obtained even if the oxygen is provided at a more or less uniform rate during a 24-hr. period.

In general, tank aeration has advantages over trickling filter aeration in that tank aeration is considerably easier and simpler to install. An aeration tank requires less space and can be located near dairy plants or residences without causing odor complaints. The chief disadvantages are the requirement of more power per pound of B.O.D. removed and the still unexplained difficulties that may occur with excessive foaming, and with floating and bulking sludge.

Aeration Equipment

The present aeration devices such as porous plates and tubes clog rapidly in most plants. Saturation of the air with steam is reported to retard clogging of plastic-wound diffusers and pretreatment with lime is also helpful. Drilled headers with holes ⅛-in. diameter or less clog quickly, while holes 3/16-in. in diameter or larger clog much less readily.

The Mallory type of diffuser with drilled headers, each hole equipped with a short (2-in.) piece of 3/16-in. tubing, has been reported (6) (7) to show much less clogging.

Suction jets (such as Penberthy eductors) produce small air bubbles with considerable surface area per cubic foot of air and also give a good breakup of sludge particles. To be effective as suction jets they must be used in relatively shallow tanks with a high pressure recirculating pump. Power costs per lb. of B.O.D. removed are high and the pump pressure may cause excessive foaming.

These jets when supplied with air under a pressure equal to the static head in the tank and with recirculated aeration tank liquid give more oxidation per jet and more efficient power utilization than when operated as suction jets using air at atmospheric pressure. If the pressure of the recirculating liquid through the jet is kept at about 15 p.s.i., excessive sludge breakup and foaming seem to be eliminated.

The larger the minimum diameter of the jet the less the tendency to clog. However, when a suitable strainer is installed and kept cleaned the clogging even of No. 4 jets is practically eliminated. The small jets (No. 4) are reported to be more efficient as air eductors than the larger jets (No. 7).

Mechanical aerators may require both a motor-driven agitator and a blower and may have interesting possibilities (20) (21).

Operation

Several investigators maintain that a tank aeration plant requires more expert operation than a trickling filter while the latter will take shock loads better. Experience indicates that this is not necessarily true. Probably the same reserve capacity can be provided in aeration tank systems as in trickling filter systems for less original investment. Any aeration tank that contains a large amount of well-aerated biological sludge probably has a reserve capacity for taking care of sudden loads of milk solids more or less in porportion to the available amount of well-aerated sludge.

It is probable that the most important factor in successful dairy waste disposal is the interest of management and operators in good plant maintenance and waste saving. These are far more important than the type of disposal unit.

In spite of the inherent shortcomings of aeration tank systems a large number of recent installations

are of this type. It is hoped that sufficient experience will be gained in the near future so some of the difficulties can be eliminated.

As mentioned previously, there are many different ways of operating aeration tank systems. In some the operation is similar to a regular activated sludge plant with a relatively short aeration period (3 to 6 hrs.) and maintenance of a relatively low sludge concentration in the mix tank (10 to 20 per cent) by a low rate of sludge return and by daily discharge of excess sludge to a digester or drying beds. Other plants use long aeration periods (1 to 2 days) and maintain a high sludge concentration (40 to 70 per cent) in the mix liquor by using high rates of sludge return. In general they attempt to keep the discharge of excess sludge to a minimum.

Recently several batch aeration plants have been installed (14). Reportedly these were designed for sufficient sludge burn-up to eliminate the disposal of excess sludge. While these plants have the advantage of simple designs they use considerable power and have considerable trouble with foaming and loss of sludge.

Claims have been made that it is possible to operate without discharging any excess sludge and to maintain a more or less constant sludge volume by endogenous oxidation in the aeration tank (16). So far no supporting data have been submitted from commercial operations. A report (24) claims it is possible to obtain 70 per cent "burn-up" of the sludge. Assuming the temperature was fairly high (86° F.), this would appear to check with practical experience in other plants.

It is quite difficult to get good reliable data because of the tremendous variations in the temperature, waste volume, waste strength and waste composition. Reliable data can be obtained only by prolonged continuous sampling in proportion to the flow, together with frequent checks of the mix liquor.

Aeration Tank Facts

The authors' considerable experience and careful study of the many confusing reports in the literature have resolved a few fundamental facts:

1. Milk wastes are exceptionally easy to treat by aerobic fermentation in aeration tanks. The lactose is quickly converted to simpler products. Protein is also split and is digested by the microorganisms. Milk fat appears not to be a problem. About one-half of the B.O.D. of the milk waste is converted to bacterial cells and one-half to gas. The final result is a fairly rapid and excellent B.O.D. removal from the clarified solution, but a considerable build-up of B.O.D. in the sludge.

2. Where the waste contains a relatively large proportion of whey (particularly deproteinated whey) the fermentation in the aeration tank may be helped by the addition of assimilable nitrogen compounds. This definitely appears to improve sludge settling characteristics and the effluent quality.

3. By extended aeration the sludge itself is aerobically digested to a considerable extent. However, no data have been reported demonstrating the maintenance of a constant sludge volume in a commercial aeration system without voluntary or involuntary discharge of sludge. On the contrary, in all systems that have been checked to date, there is definite evidence that some sludge is discharged regularly either voluntarily or through foaming or with the effluent.

4. Temperature is important. Optimum results both for bio-oxidation of milk waste and for endogenous oxidation of the sludge appears to be about 86° F. At this temperature the rate of endogenous oxidation is approximately one-tenth the rate of the fermentation of the waste itself. At 68° F. the rate of fermentation is

greatly reduced (about 38 per cent) and the rate of endogenous oxidation of the sludge appears to be practically stopped. At 50° F. the rate of fermentation is stopped for all practical purposes in commercial waste disposal plants even though, in laboratory experiments (17), the fermentation is still occurring at a measurable rate (about 37 per cent of that at 86° F.).

5. At present it seems doubtful if it is possible to operate milk waste aeration tanks consistently without removing some excess sludge. Even if commercial dairy waste contains only milk solids and if the aeration tank is operated at around 86° F., it is still probable that the microorganisms build up cell material that is not readily digested by endogenous oxidation. This material must finally be discharged either as suspended matter in the effluent or as excess sludge. However, the excess sludge volume can be greatly reduced by endogenous oxidation. Furthermore, it appears the sludge discharged, voluntarily or involuntarily, has a relatively low B.O.D. and can be handled easily on drying beds without previous treatment in an anaerobic digester.

Anaerobic Treatment

In general, uncontrolled anaerobic treatment of dairy wastes in lagoons or tanks tends to produce bad odors. Although it is cheap, it is not desirable in most locations. Septic tanks with underground drainfields can be made to work on dairy waste from small plants if the dimensions of the tank are large enough and if the temperature of the waste is maintained near 90° F. Design data formerly recommended a tank volume of at least twice the daily flow, but most likely this is too small if good B.O.D. reduction is to be obtained. It should be remembered that a large part of the B.O.D. in dairy waste is soluble and consequently the retention time must be sufficient to allow digestion of soluble B.O.D., in addition to the digestion of settled B.O.D. as in a septic tank handling domestic wastes.

Septic tanks or digesters for dairy waste can be started by filling, with water at 90° F., some lime and some ripe septic sludge from a sewage treatment plant. Under these conditions it does not appear to be difficult to keep the tank from souring. When operating properly, relatively large volumes of carbon dioxide and methane are formed and little or no hydrogen sulfide. If an attempt is made to operate a septic tank (or digester) on dairy waste without seeding or at a low temperature it will usually go sour. The acidity will help to precipitate protein, but protein digestion is often slowed down so much that little or no B.O.D. reduction takes place. Then the tank fills up with undigested protein and bad odors occur.

Apparently, few septic tanks are used at present in the dairy industry for direct treatment of dairy waste, although there are a number of digesters in use for the treatment of sludge from trickling filters or excess sludge from aeration or activated sludge plants.

Chemical Precipitation

About thirty years ago there was considerable interest in the use of chemical precipitation in the treatment of dairy waste. A number of batch type treatment plants were installed, using either iron or aluminum salts to precipitate the protein in the waste. The process had two great disadvantages: (a) the lactose was not affected and remained in clear solution and (b) the sludge was voluminous and created quite a disposal problem.

Various combinations of aeration and chemical precipitation, such as the Guggenheim and Mallory processes, have also been tried. In general they have been too complicated for the small treatment units needed in the dairy industry.

Summary

The trend in the dairy industry is to larger manufacturing plants equipped to utilize all by-products, thereby eliminating waste. However, overproduction and low prices are a serious handicap to this trend.

Dairy products are highly concentrated and perishable and their wastes have a strong polluting effect; in addition, there are pronounced seasonal, daily and hourly variations in volume and strength of the wastes. The importance of waste segregation and pretreatment of the floor wastes for separation of grit, fat and other particles cannot be over-emphasized.

Continuous automatic sampling over extended periods of time to assess improvements in waste savings is important for design and treatment purposes.

Waste discharge to municipal sewers is preferred wherever it is feasible. Irrigation methods are receiving considerable attention, while interest in anaerobic digestion and chemical precipitation appears to be slight. High-rate recirculating trickling filters are still giving excellent and economical treatment, but aeration tanks are considerably cheaper and simpler to install. Many types of aeration tanks and aeration devices are being used. The important factors are: (a) maintenance of temperatures above 70° F. (80° F. to 90° F.) and (b) good agitation with aeration devices that do not encourage foaming.

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PUBLIC SEWAGE TREATMENT PLANT CONSTRUCTION—1954

A summary of construction of public sewage treatment works for the calendar year 1954 is contained in an 18-page report released by the Division of Sanitary Engineering Services, U. S. Public Health Service, under the title "Public Sewage Treatment Plant Construction—1954," and designated PHS Publication No. 453.

According to the report, contracts amounting to $227,500,000 for 716 sewage treatment plants, including in many places interceptor sewers, were awarded by U. S. municipalities during the year. The cost of 366 new plants was $143,200,000, the remaining $84,300,000 providing for additions, enlargements or replacements for 350 existing plants. The following contract totals for 1948–1954 indicate the record expenditures for sewage treatment facilities:

Year	Actual Dollars (millions)
1948	158
1949	180
1950	203
1951	177
1952	137
1953	191
1954	228

It is currently estimated that annual expenditures of $250,000,000 for municipal sewage treatment works construction are required to keep pace with needs developing as a result of population increase and plant obsolescence.

An appendix of 12 pages lists, by community, the individual sewage treatment construction contracts awarded during 1954, giving the type of construction and cost in each case.

Stream Pollution

SURVIVAL OF COLIFORM ORGANISMS IN PACIFIC OCEAN COASTAL WATERS *

By Isadore Nusbaum and Richard M. Garver

Respectively, Water Pollution Control Engineer,† San Diego Regional Water Pollution Control Board, San Diego, Calif., and Lt. J.G., M.S.C., USN, U. S. Navy Preventive Medicine Unit No. 5, U. S. Naval Hospital, San Diego, Calif.

This study was made to obtain information on the viability of coliform organisms in saline waters of the Southern California Coastal Area. Specifically, the investigations were performed on the waters of San Diego Bay and Pacific Ocean bordering the coastline of San Diego County, Calif. Forty-one million gallons per day of undisinfected, partially treated municipal wastes are discharged into San Diego Bay. The coastal waters of Southern California daily absorb the liquid wastes of an estimated 6,000,000 people. Almost all of these wastes are discharged in areas contiguous to beaches, industrial and military installations requiring a "bacterially safe" water.

Historical Background

Adequate reviews of the literature on the viability and dispersal of fecal bacteria in the sea may be found in "Marine Microbiology" by ZoBell (1) and the studies of the Woods Hole Oceanographic Institution (2) (3) (4). It is of interest to note that many of the reports are contradictory. Ketchum (3) notes that results have been reported varying from death rates far more rapid than those found in fresh water to information that sea water is neither antiseptic nor inimical to enteric bacteria. Peculiarly enough, despite the work of many investigators showing that enteric organisms may persist for long periods in autoclaved sea water, statements are still to be found in recent reports (5) (6) that sea water, per se, is detrimental to the existence of these organisms.

Some studies (7) have shown such an extremely rapid reduction of enteric organisms in sea water that doubt was expressed as to the public health significance of waste discharges into the sea. On the other hand, Buttiaux and Leurs (8), following a series of optimistic reports by several French investigators, cautioned against undue reliance on the so-called antibiotic effect of sea water on the bacteria in municipal wastes. Although these two investigators hesitated to generalize on their findings, it was shown that under the conditions used *S. typhi, S. paratyphi, B.* and *S. enteritidis* persisted with little change in numbers for periods in excess of 24 hr. At the same time, controls using spring water showed reductions of 75 to 100 per cent in the numbers of organisms in 22 hr. and 93 to 100 per cent in 44 hr.

It is to be expected the circumstances influencing the existence of enteric organisms in an aqueous media would, or might, vary considerably with the locale. Some observers have

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† Presently Sanitary Engineer, USPHS, Detroit, Mich.

FIGURE 1.—Map of San Diego Bay, Calif., showing sources of bacterial pollution.

demonstrated an apparent difference in the viability of enteric organisms not only in different bodies of saline water but also in adjacent areas of the same body. However, this effect (5) (9) has been frequently noted for fresh water as well as for sea water.

San Diego Bay, the waters of which were used for a large part of this study, is shown in Figure 1. The only fresh water normally discharged into the bay is in the form of wastes. The rivers and streams shown are dry throughout most of the year. A company extracting salt from sea water is located at the extreme south end of the bay. Sources of waste containing significant bacterial populations are shown in Figure 1. Untreated sewage is also discharged from large Naval vessels moored in the bay. The south section of the bay, zone C, is shallow with an average depth of about seven feet with large portions exposed at low tide. Approximately 95 per cent of the wastes are discharged to the middle bay, zone B.

The mean tidal range in San Diego Bay is 4.2 ft. with an average of 1.9 tides per day. The tides are characterized by diurnal inequality. The effect of the tides with respect to waste

disposal is felt principally in the north end of the bay, zone A.

There are no extreme differences in the salinity of the bay. Vertical stratification of the waters of San Diego Bay where it exists is mainly thermal. Water temperatures vary from a low of 12° C. in the winter to a high of 24° C. during the summer.

Investigational Techniques

Samples of bay and ocean water were filtered through cotton to remove gross extraneous matter and placed in 1-gal. glass jugs which were incubated in a running water bath in the laboratory. The temperature of the water bath was maintained within 1° to 2° C. of the bay temperature at the time of sampling. The water samples were inoculated with either washed suspensions of a laboratory culture of *E. coli* or with one part per 100 of cotton-filtered San Diego Sewage Treatment Works primary tank effluent. In some cases San Diego Bay waters naturally contaminated were incubated without further inoculation. Every effort was made to duplicate normal environmental conditions within the limits of an in vitro experiment.

A portion of each sample was removed daily and the coliform organism population was determined by the presumptive method with five tubes in each of three or more serial dilutions using double strength lactose broth. Ninety-nine per cent of the several hundred individual determinations were confirmed in brilliant green lactose bile broth so additional confirmations were not made. The ocean waters in the San Diego area are virtually free from coliform organisms except where some source of contamination is near. Except for waterfowl, municipal and ship wastes are the principal source of coliform organisms in San Diego Bay. Inoculated samples of bay and ocean water were also placed in cellophane dialysis tubing and suspended in San Diego Bay. Determinations were made using autoclaved sea water, prepared B.O.D. water, tap water and stored sea water.

Total bacterial counts were obtained during the course of some experiments by inoculating solid sea water media (1). Lactose broth was also prepared using sea water instead of distilled water for some of the experiments.

The membrane filter was investigated for use in this work and discarded for several reasons. The most important reason was that it would have taken a research project merely to establish its suitability for the study. The modified E.H.C. Endo medium did not give results comparable with the fermentation tube method. In a recent investigation, which has not yet been reported, another laboratory using E.H.C.-B.G.F. medium isolated three different types of colonies, only one type of which showed sheen. However, all three types of colonies confirmed for the coliform group. The sheen colonies were later determined to be *E. coli*. Another colony type was found to be *Aerobacter aerogenes* and the third type was another coliform variant. The source of these organisms was primary sewage treatment plant effluent. Strict interpretation of the membrane filter results as compared to the M.P.N. fermentation tube data was impossible without a great deal of additional information.

Experimental Data

ZoBell (1) has stated that artificial, synthetic, diluted or autoclaved sea water does not necessarily simulate natural sea water and the biological properties of the latter may vary greatly. Any sample of natural sea water that has been removed from its source and placed within the artificial boundaries of a container does not simulate natural conditions. In fact, the authors were unable to determine that what occurred under controlled experimental conditions exactly dupli-

cated the phenomenon occurring in the bay or ocean.

A decision that had to be made was whether to use sewage directly as a source of the bacteria or to use a laboratory culture of *Escherichia coli*. Another decision concerned the numbers of bacteria to be inoculated in the water. Although these points may seem trivial, it did not seem logical to compare in vitro experiments in which neither the quantity nor the quality of the bacteria population was similar with in vivo results. For example, the sewage contained at least three different groups of coliform organisms, whose viability might not be at all comparable to a specific *E. coli* laboratory strain, together with innumerable other bacteria and suspended and dissolved organic and inorganic matter. Coliform bacteria in the primary sewage varied from 200,000 to 800,000 cells per milliliter and after immediate dilution through the existing sewage outfalls, counts of 5,000 to 30,000 cells per milliliter were found; whereas in many investigations bacterial populations of the indicator organism of from 10^7 to 5×10^8 cells per milliliter have been used. Although theoretically the death rate of the organisms under consideration should not vary because of initial concentrations, actually it was decided not to use pure cultures in extremely high concentrations for the general purposes of this work. The initial lag periods for *E. coli* suspensions of about 10^7 cells per milliliter in sea water and *E. coli* or sewage dilutions of about 5,000 cells per milliliter appeared to be the same, but the death rate in the subsequent phase appeared about twice as rapid for the former.

An initial lag period, during which the coliform population remained somewhat stable, lasted from less than 24 hr. to four days when natural sea water was incubated in 1-gal. glass jugs in the laboratory. The length of the lag period varied in general with the season of the year, although this property was not consistent during any season. The lag period and the coliform variability was similar to that found by Vacarro, Ketchum et al. (2) (3). The existence of this lag period takes on far more significance when one considers that it is almost impossible to locate an outfall in the populous regions where under general or unfavorable current conditions the diluted effluent will not reach sensitive areas within 24 to 96 hr.

A number of parallel experiments were run using natural sea water, dechlorinated tap water and a standard buffered dilution water. All the samples were inoculated with filtered primary sewage effluent. The results in Table I are typical of a series of these determinations:

TABLE I.—Comparative Study of Incubated Samples Using Different Dilution Waters

Inoculation Period (Days)	Natural Sea Water (M.P.N.[1])	Dechlorinated Tap Water (M.P.N.[1])	Buffered Dilution Water (M.P.N.[1])
Initial	490,000	330,000	140,000
1	170,000	240,000	3,300
2	220,000	240,000	1,100
3	33,000	240,000	950
4	4,900	240,000	400
5	1,400	70,000	700
7	310	13,000	790
8	490	3,300	1,100
9	330	13,000	490

[1] Coliform per 100 ml.

These data revealed, that natural sea water cannot be compared with a treated chlorinated tap water or a synthetic dilution water. If a comparison is to be made it should be made with natural fresh water. However, the data did show that sea water is not alone in demonstrating rapid reductions in bacterial concentrations on storage. This phenomenon is almost as old as bacteriology. There have been many reports of the rapid decrease in coliform organisms in natural fresh waters. The excellent studies of the U. S. Public Health Service on the Ohio River Basin are typical. In a discussion of the via-

bility of coliform organisms in water by Prescott, Winslow and McCrady (10) some figures are given on the change of coliform organisms in the Ohio River between Cincinnati and Louisville. Strangely enough the death rate demonstrated by the Ohio River data is almost identical with some other information in the same reference from the Massachusetts Department of Health on the purportedly rapid rate at which the coliform group dies in sea water.

The data in Table I on the buffered dilution water are perhaps indicative of the difficulties one may encounter. The extremely rapid initial change in bacterial counts was surprising. The buffered water was identical with standard B.O.D. dilution water. The distilled water used to prepare the dilution water was stored in a stainless steel tank containing a brass fitting and soldered joints. Although traces of the metals could not be detected in the distilled water, it was probable that enough had been dissolved to establish some oligodynamic action. Distilled water from another source was used and the difficulty disappeared. It would not be unusual to find substances with an oligodynamic action in natural waters or from the wastes discharged.

Autoclaved Sea Water

Autoclaved sea water inoculated with washed suspensions of *E. coli* exhibited the same marked change on the viability of the test organism which had been reported by others (2) (3). Table II represents one of a series using an inoculum of sewage in autoclaved and reaerated autoclaved sea water.

There was no practical difference between the results obtained on the autoclaved and the reaerated sea water. Although dissolved oxygen determinations were not made during the course of the experiment, the autoclaved water contained no initial dissolved oxygen and the reaerated water was saturated with oxygen. It appears that autoclaved sea water is a better habitat for the coliform group than fresh water and would probably make an excellent dilution water. It has been frequently reported that the enteric organisms will not propagate in sea water media. All of that work appears to have been done with solid media. Lactose broth was prepared using distilled water, sea water and preautoclaved sea water and inoculated with effluent from a primary treatment sewage plant. Two determinations using the same sewage were run on each broth. Specifically it is believed that the normal saline constituents of sea water are not antagonistic to enteric organisms. Table III shows the comparative results of incubated sea water, preautoclaved sea water and standard lactose broth.

TABLE II.—Comparison of Incubated Samples of Autoclaved Sea Water

Incubation Period (Days)	Natural Sea Water (M.P.N.[1])	Autoclaved Sea Water (M.P.N.[1])	Reaerated Autoclaved Sea Water (M.P.N.[1])
Initial	460,000	1,300,000	350,000
1	230,000	540,000	230,000
2	4,900	1,600,000	540,000
3	2,700	1,600,000	540,000
4	3,500	540,000	350,000
5	700	350,000	540,000
6	1,700	920,000	140,000
7	700	350,000	350,000
8	230	920,000	350,000

[1] Per 100 ml.

Temperature

An attempt was made to determine the effect of temperature on the viability of coliform organisms in natural

TABLE III.—Comparative Study of Incubated Sea Water and Preautoclaved Sea Water

Lactose Broth Distilled Water (M.P.N.[1])	Lactose Broth Sea Water (M.P.N.[1])	Lactose Broth Preautoclaved Sea Water (M.P.N.[1])
49,000,000	49,000,000	23,000,000
23,000,000	17,000,000	23,000,000

[1] Per 100 ml.

sea water under laboratory conditions. Samples were incubated at 5° C., 18° C. and 30° C., although it would be rather unusual to find sea water temperatures of 5° C. in Southern California. There was little difference between the samples incubated at 18° C. and 30° C. These samples showed an initial population stability of one to three days followed by a rapid decrease. The 5° C. samples showed insignificant changes in coliform counts for periods up to 9 days.

It would be impossible to say whether this reduction in mortality is due to reduced effectiveness of the postulated antibiotic activity or to the reduced metabolism of the organisms at low temperatures. It has been found frequently that some substances appear to be less toxic at low temperatures due to the reduced metabolic activity of the test organism.

Sedimentation

Experiments to determine the effect of sedimentation were conducted in the laboratory with inconclusive results. It was impossible to simulate natural conditions affecting flocculation and sedimentation. Filtered sewage used for an inoculum did not contain sufficient particulate matter for agglomeration.

Sea Water Samples

Additional experiments were planned using inoculated samples of sea water in cellophane dialysis tubing suspended in the bay.

The results showed a definite increase in the initial lag phase and there appeared to be some increase in coliform bacteria numbers. Several typical examples are shown in Table IV.

Total bacterial counts were also determined on solid sea water media. The total counts in the dialysis tubing were as much as 1,000 times greater than the total counts in the laboratory incubated samples. It is quite apparent that the container in which the experiment is conducted is of paramount importance. It should also be apparent from these data and other sources that while certain changes which take place in the laboratory are of the same order as the natural phenomena, they may not even be related.

A non-filterable, heat labile material which demonstrates a considerable effect on enteric bacteria in in vitro experiments appears to be present in natural sea water. This substance has been accredited to other organisms in the sea and to bacteriophage. Peculiarly enough, samples taken in the ocean in areas virtually free of bacteriophage and having low total bac-

TABLE IV.—Bay and Laboratory Incubation of Inoculated Sea Water Samples

Days Incubated	Sample 1		Sample 2		Sample 3	
	Lab. Incub. In Glass (M.P.N.)	Bay Incub. Dialysis Tubing (M.P.N.)	Lab. Incub. In Glass (M.P.N.)	Bay Incub. Dialysis Tubing (M.P.N.)	Lab. Incub. In Glass (M.P.N.)	Lab. Incub. Dialysis Tubing (M.P.N.)
Initial	5,400,000	5,400,000	330,000	330,000	170,000	170,000
1	3,500,000	9,200,000	170,000	490,000	220,000	490,000
2	130,000	24,000,000	26,000	3,500,000	33,000	790,000
3	17,000	3,500,000	11,000	1,100,000	7,000	1,700,000
4	11,000	700,000	1,300	49,000	—	—
5	4,900	1,700,000	3,300	49,000	3,300	790,000
6	11,000	1,400,000	490	23,000	1,700	2,400,000
7	—	—	—	—	200	1,300,000
8	—	—	—	—	310	79,000

teria and phytoplankton populations demonstrated the antibiotic action in vitro. Whereas autoclaved sea water samples placed in glass containers and inoculated with sewage undoubtedly containing large numbers of bacteriophage showed little change.

San Diego Bay Factors

Available bacteriological data on San Diego Bay, much of which had been obtained at the same time as this study, was re-examined. Bacterial pollution did not appear to exhibit a seasonal pattern despite the fact that in vitro tests showed a much greater antibiotic action in summer than in winter. The coliform organisms disappear rapidly in the large shallow south section of the bay contiguous to some of the heaviest pollution. In vitro tests comparing water from this end of the bay with other sections and with ocean water showed no marked difference in antibiotic action. During the extreme low tides of the area (1.0 to 1.9 ft. below datum) M.P.N.'s as high as 24,000 per 100 ml. have been found and can be traced as far as six miles from the San Diego Sewage Treatment Works outfall. At other times and tides high coliform concentrations are not found more than one to two miles from the outfall.

The flushing characteristics of San Diego Bay are not well defined, but the major changes in coliform population are taking place within the bay. For example, the mean M.P.N. in the bay, if the sewage were dispersed uniformly, would be 35,000 for each day's discharge. This is based on a rough calculation of the mean tide volume of the bay and assuming 41 m.g.d. of sewage plant effluent containing an average M.P.N. of 50,000,000. Presumably it would be much higher based on available information on the initial lag period. The average M.P.N. in the central section of the bay may approach this value at times, but it is generally lower. In the south and north sections of the bay it is much lower. At Ballast Point, the entrance to the harbor, the mean M.P.N. on an ebbing tide is about 100.

In general, the following have been accredited with having some effect on bacterial numbers in sea water: antibiotic action due to some organic substance, bacteriophage, salinity, sunlight, flocculation and sedimentation, adsorption, predatory and filter feeding organisms, and dilution. The authors doubt that bacteriophage, salinity, or sunlight have any special significance. It is extremely doubtful that the germicidal effects of solar radiation penetrate beyond 5 to 60 cm. ZoBell (1) has stated that if there is any direct effect of sunlight on bacteria in sea water, it is obscured by other factors.

Flocculation and sedimentation are probably important factors. Mud samples from the bay bottom have shown coliform densities of from two million per 100 ml. to more than 2.4 billion per 100 ml. of wet mud. In general the counts varied inversely with the distance from the outfall.

In a bay such as San Diego Bay, which is large and shallow with many surfaces for the development of filter feeding organisms, large numbers of bacteria must be ingested daily. Organisms such as mussels, clams and tunicates may filter 6 to 10 gal. of water per day. With the tremendous population of these animals found in San Diego Bay, particularly in the central and south sections, it would appear that many bacteria would be removed.

Adsorption of the bacteria on suspended matter in the water may be an important factor. Weiss (11) has reviewed available information on adsorption and demonstrated, in vitro, such effects. Additional data, particularly on sea water, is necessary.

Summary and Conclusions

A high degree of uncertainty still prevails with respect to the viability of enteric organisms in sea water.

Even less is known on the fate of pathogens in the sea than on the tracer organisms commonly used.

Existing information must be re-evaluated with respect to the environment in which the experiments were conducted. These studies have shown that significant differences exist with respect to the treatment given the waters used, the source of the test organisms and the container in which the experiments were conducted. Sea water alone is not antagonistic to coliform organisms because of its salinity.

Under the conditions of the experiments in this study, coliform organisms have been found to persist in sea water for relatively long periods. Additional data are required comparing the effects of dispersal of bacteria containing wastes into fresh as well as sea water. It has been demonstrated in many instances, that the viability of enteric organisms in fresh water is not appreciably greater than sea water and may actually be less.

Acknowledgments

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The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the U. S. Navy Department or the Naval Service at large.

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SLIME FORMATION IN POLLUTED WATERS*

I. Laboratory and Field Study Methods

By H. Heukelekian and E. S. Crosby

Rutgers University, New Brunswick, N. J.

The primary objective of these investigations was to obtain basic information on the significant factors affecting the nature and amount of slime formed on submerged surfaces in polluted waters. Fundamental information from these studies was then utilized to evaluate when, where and why slimes may become a nuisance and to develop a basis for their control.

Slime may be defined as the viscous or gelatinous film formed on submerged surfaces, including both living and associated non-living matter. The film varies widely in composition and amount, depending on the diverse physical, chemical and biological factors of the environment.

The environmental conditions of submerged slime growths include two groups of factors. *"Surface factors"* are concerned with the type of surface on which slime forms. *"Medium factors"* are related to the character of the liquid in contact with these surfaces.

Plan of Research

Investigations were designed to study the fouling of submerged surfaces by mixed, natural populations of organisms in polluted waters. No attempt was made to identify all organisms present or to determine the effect of specific organisms or groups of organisms. The objective was primarily to determine how the film varied under certain environmental conditions rather than to study the effect of the film on the environment.

The studies of slime formation will be presented in three parts:

I. Laboratory and field study methods.

II. Factors affecting slime growth.

III. Nature and composition of slimes.

Two other phases of this study have been previously reported and will not be included in this series. These earlier publications relate to: (a) biological growths in petroleum refinery waste water (1), and (b) protective coatings and slime growths (2).

Before studies could be undertaken to evaluate the influence of various factors on the quantity and composition of slimes, it was necessary to develop experimental methods and procedures. These fall into two main categories: laboratory methods and field methods. The laboratory methods were designed to reproduce as nearly as possible conditions prevailing in the field, so that the influence of specific factors could be isolated and controlled more completely than is possible under field conditions. It is hoped that the method developed will be of value to others interested in studying slime formation.

Laboratory Methods

In all laboratory studies, standard glass microscope slides, 3-in. × 1-in., were employed as the test surface.

Four basic types of immersion were employed: static, air lift recirculation, tank recirculation, and dipping.

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University.

Other methods of submerging the test slides were modifications of the four basic types.

Submerged Static Method

The submergence of fixed surfaces (microscope slides) without motion of either the liquid or the fixed surface has been termed the "submerged static" method. In the submerged static method, the slides were placed on end in grooved Lucite holders, and the holders were submerged in 800 ml. beakers containing 500 ml. of the immersion liquid. The strips of Lucite were provided with parallel grooves, 3-in. × 1-in. × ¼-in. so arranged that the microscope slides would stand vertically in the Lucite holders.

The use of static surfaces with moving liquid was studied by two different methods: air lift recirculation and tank recirculation, employing several modifications of each method.

Exposed Air Lift Recirculation

"Air lift recirculation" involved the use of fixed suspended slides, the test liquid being recirculated by air lift. Two variations of this method differed only in the location of the slides: for "exposed" air lift recirculation the slides were located above the liquid reservoir, while in the "submerged" method the slides were continuously located beneath the liquid surface.

In exposed application, the recirculation apparatus illustrated in Figure 1 was employed. This consisted of an air lift device and plastic slide holder fitted to a rubber stopper, the stopper serving to suspend the apparatus in a one liter graduated cylinder. The aerated flow from the air lift was discharged on the plastic baffle of the slide holder. The liquid flowed down over the glass slide, which was supported at an angle of about 30 degrees from the vertical position.

For exposed operation, a 400 or 500 ml. volume of liquid was placed in

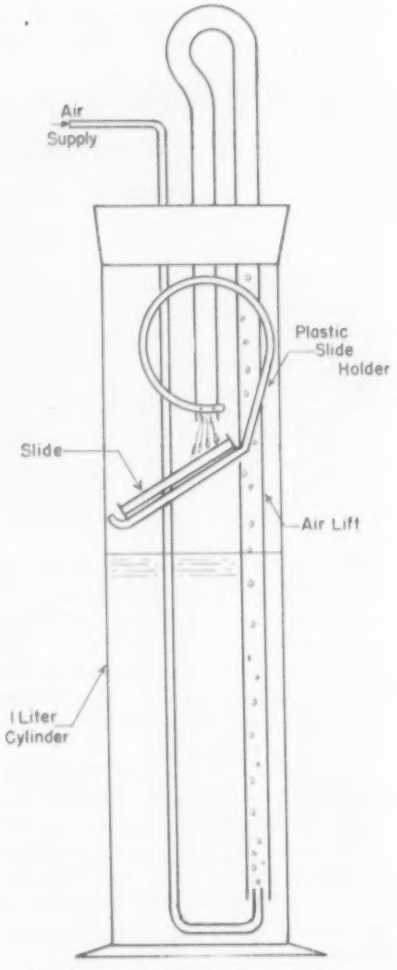

FIGURE 1.—Schematic diagram of air lift recirculation system.

each of the cylinders, and the air lines were connected to a manifold. Flow of air to the manifold was controlled by a needle valve, and regulated by means of a flow gauge or manometer. Flow of air to the individual cylinders was controlled by separate screw clamps on the respective air lines. Air discharged from the manifold to each air lift at a rate of 0.5 l. per minute produced a recirculated liquid flow of 30 to 40 ml. per minute,

or 2.5 l. per hour. Twelve of these air lift units were operated simultaneously, with a single microscope slide in each unit.

Submerged Air Lift Recirculation

In "submerged air lift recirculation" the plastic baffle was removed from each unit. A new plastic slide holder containing two slides was suspended by nylon fishing leader, at a level below the surface of the main liquid reservoir. Slides were immersed in a vertical position, and 1 l. volumes of immersion liquid were used. The air flow employed (650 ml. per min.) produced a liquid recirculation flow of 12 l. per hour. Twelve of these units were operated simultaneously.

Tank Recirculation

The "tank recirculation" method, illustrated in Figure 2, also employed fixed surfaces immersed in the liquid. The tanks permitted as many as 70 microscope slides to be simultaneously immersed in one tank, under the same conditions. Studies were made using standard aquaria having glass sides and a slate bottom. These aquaria were 10 gal. in capacity, measuring 19.5-in. × 10-in. × 11.5-in. deep. Slides were supported vertically in 1/16-in. slots; the slots were milled, ½-in. apart, in a base made of Lucite (10.5-in. × 5-in. × ¼-in.) and placed on the tank bottom. A center baffle of Lucite (15-in. × 6-in. × ⅛-in.) was inserted in a ⅛-in. slot in the base.

In operation, from 12 to 36 l. of sewage were added to the tank; the Lucite base, with slides and center baffle inserted, was centrally located in the tank and fixed in place by an overhead clamp. The sewage filled the tank to varying depths, but the surface was well above the slides and below the top of the center baffle. In studies using volumes greater than 16 l. per tank, a higher (12-in.) center baffle was used.

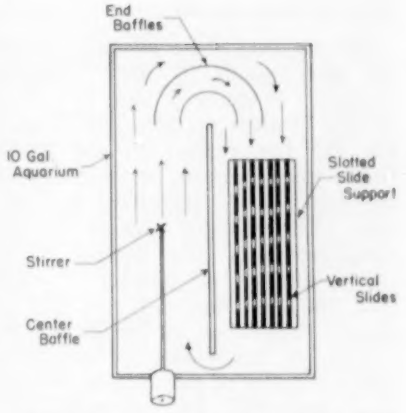

FIGURE 2.—Schematic diagram showing the top view of the recirculation tank system.

The shaft of a single speed laboratory stirrer (1/150 h.p., 1,550 r.p.m.) was obliquely inserted into the sewage in the channel opposite the slides. The position of the stirrer was adjusted to keep surface disturbance and reaeration at a minimum. Various baffle arrangements were tried to reduce surface agitation and to produce an even flow. Batch operation employed various depths (9.5 to 28.0 cm.) and volumes (12 to 36 l.) of sewage. The sewage was changed at daily intervals.

In continuous operation of tank recirculation, sewage was added and removed continuously. Sewage was supplied from overhead bottles, using an automatic gravity feed, and was removed from the tank by a siphon outflow. The rate of effluent discharge was regulated by flow through capillary tubing, the size of the capillary and the elevation of the outlet being varied to control the rate to the desired point. The direction of flow was also controlled by inserting diagonal and curved baffles at tank corners to even the flow. A carborundum diffuser was employed for aeration of the tank contents.

Dipping Methods

The majority of the laboratory studies were made by the "dipping method" (Figures 3 and 4). This method employs the principle of moving the test surface in the liquid rather than pumping or recirculating the liquid past a stationary test surface. The primary reasons for the development of this method were: (a) to increase the number of slides that could be immersed, and (b) to permit comparison of results within a range of environmental conditions. Two variations of the dipping method were employed. In "alternate dipping" the test surface was dipped into and out of the liquid at a known rate and velocity. A "submerged dipping" method involved up and down movement of the continuously submerged test surfaces at a known velocity.

The dipping apparatus consisted of a tubular copper frame, having a central axis supported by angle iron uprights. The frame was tilted up and down through a vertical distance of 6 to 8 in. by means of a lever or driving link; the lever was attached to an off-center pin located on the face of the driving pulley. The tilting distance was varied by sliding the connecting link on the frame closer to or farther from the axis. The rate of dipping was varied by the use of a Graham variable speed transmission

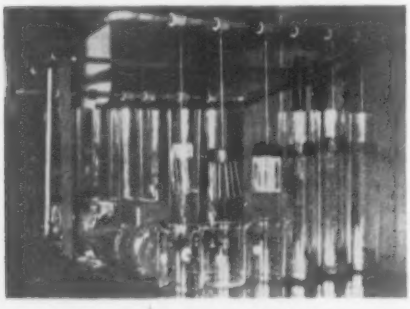

FIGURE 3.—Laboratory dipping apparatus for suspending microscope slides.

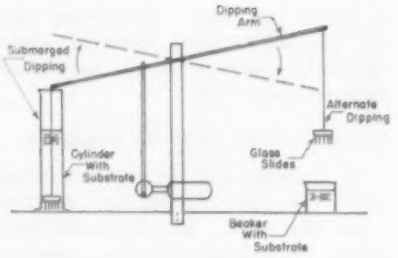

FIGURE 4.—Schematic diagram showing side view of microscope slide dipping apparatus.

attached to a constant speed motor. The speed was variable between zero and 36 r.p.m. In these studies, the rate of dipping employed was 3 r.p.m., moving the frame a distance of 14-in. in 20 sec., or at a velocity of 0.058 ft. per sec.

Various methods were tried to hold the microscope slides in the dipping apparatus. The simplest and most practical method of suspension found was the use of a No. 12 rubber stopper, having a series of parallel grooves cut in its wide surface and supported in its center by a nylon fishing leader. The leader was attached to the dipping frame by means of a short section of heavy rubber tubing, cut along one side, the nylon being threaded through a small hole opposite the cut. The section of rubber tube, when placed around the copper tube frame, held the nylon leader in place by friction, and the rubber stopper could easily be raised or lowered to the proper height. This arrangement also permitted the slide holder to be moved along the frame to any position, or be removed for inserting slides and for cleaning. The rectangular frame, 24-in. × 28-in., accommodated six rubber slide supports on each side. Eight microscope slides, numbered, cleaned, and weighed, inserted to a similar depth in each of the rubber stoppers, were used as test surfaces.

In "alternate dipping," to expose slides alternately to air and liquid, 12

short cylinders or beakers (800 ml. capacity) were employed.

In "submerged dipping" two types of containers were employed. For the majority of the experiments the "cylinder dipping" method was used, employing a series of 12 plastic cylinders 13-in. deep, made from 3¼-in. Lucite tubing, and fitted at the bottom with No. 14 rubber stoppers. These vessels had a capacity of 1.5 l.

For the "tank dipping" method, aquaria similar to those used for the "tank recirculation" method were employed. This procedure permitted dipping all slides on one side of the dipping apparatus into the liquid containing vessel.

As the "alternate dipping" apparatus operated, the slides on one side of the frame were lowered while those on the opposite side were elevated. The dipping apparatus was operated continuously for periods up to 26 days, with little or no mechanical difficulty. To sample slimes deposited on microscope slides, the slides were merely removed from the slide holder at the desired time interval. All laboratory studies employed slides at test surfaces, and the sampling procedure was similar for all.

Field Methods

Test surfaces employed in field studies were of two types: (a) Standard microscope slides, as employed in laboratory studies, and (b) large test plates made of various materials.

Slide Immersion Holders

Field methods for supporting microscope slides included various types of holders or racks made largely of copper, transite, or wood. The copper slide holders were constructed of sheet copper, folded to form two end channels 9-in. long and having a ⅛-in. inside channel width. Channels were made sufficiently wide to accommodate the thickness of two miscroscope slides placed back to back. The channels were soldered together at the top and bottom by connecting copper cross pieces. Hardware cloth (¼-in. mesh) was soldered on one side, and a door of similar material was provided on the opposite side. The hardware cloth was installed to prevent breakage of slides as the slide holders were moved around concrete walls. The door facilitated removal of slides and cleaning of the holder. A copper slide in the bottom of the trap enabled removal of microscope slides at sampling intervals. A maximum of 18 slides could be inserted into the slide holders, but the top and bottom channels were not used because of possible interference from the copper cross pieces. The slide holders were suspended from brass rods or on heavy copper wire. No corrosion of copper racks or wires was encountered either in sewage or salt water, but galvanized hardware cloth completely deteriorated after four to six months in sea water.

Since slides containing large amounts of slime could not be satisfactorily removed from the copper channels, new slide holders were made of Transite and wood. The design of these was based on the wooden holders used by Zobell for marine studies. Transite slide holders are illustrated in Figure 5. In this device, one face of each slide was exposed to growth and the other was flat against the 16-in. × 4-in. sheet of Transite. The 16 slides on each holder were supported vertically by 4-in. × 2-in. cross strips of Transite bolted to the large sheet. Slides were held in place by rubber bands, and were easily removed with no damage to the film. The holders were suspended by copper wire and were weighted down with lead strips bolted to the bottom of the Transite sheet.

Wooden slide holders, similar in principle to the Transite holders, were also provided; wood was used because of the high rate of breakage of the large Transite sheets. Both copper and Transite slide holders supported by wires were found to sway in the

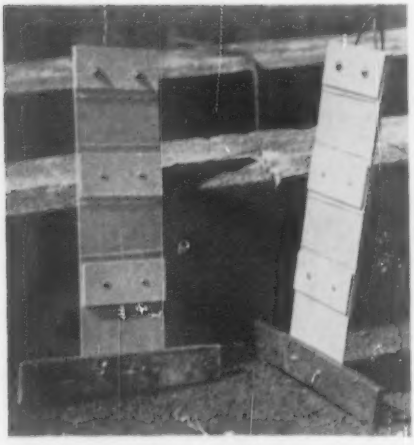

FIGURE 5.—Transite holders for suspending microscope slides.

current and to hit the walls of channels or treatment units, with resultant breakage and loss of slides. Transite sheets, as a back for slide holders, were not sufficiently sturdy, and lead weights were found to break off in the current.

To meet these objections, new slide holders (Figure 6) having solid wooden supports were constructed of 1-in. × 4-in. pine lumber, 8-ft. long.

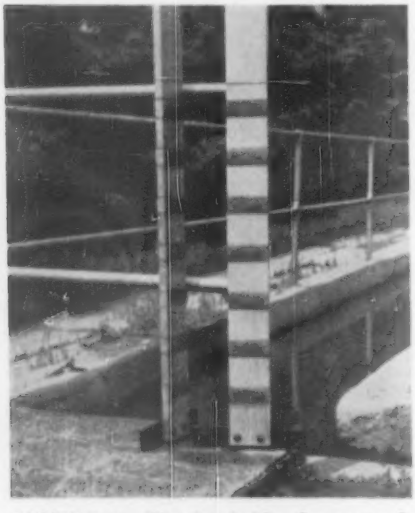

FIGURE 6.—Wooden holder for suspending microscope slides.

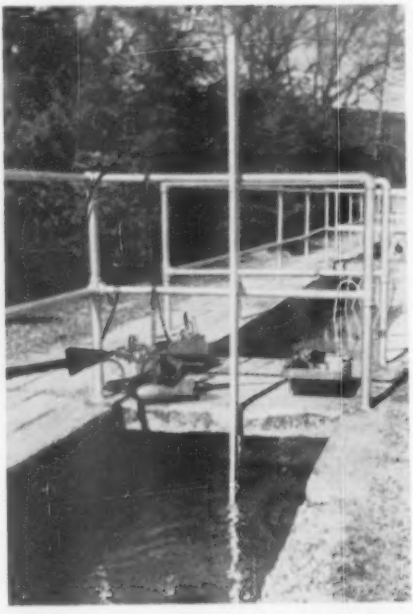

FIGURE 7.—Installation of wooden holder for microscope slides. (Arrow indicates Gurley Current Meter.)

The wood was protected with two coats of aluminum paint. Transite cross strips, similar to those used on the Transite slide holders, separated the rows of slides and heavy rubber bands were used to hold the slides in place.

Each slide holder was solidly mounted in its selected plant location by means of two flat iron strips bolted to the wooden support. The iron strips were bent to form hooks over the pipe guard rails at the plant, as illustrated in Figure 7; the entire wooden support was easily removable for slide sampling. Lead weights were bolted to the bottom of the support to counteract the buoyant effect of the wood. Slide holders mounted in the stream were supported on steel rods driven into the earth bottom and reinforced by guy wires attached to trees on the stream margins.

A modification of the wooden slide holders, Figure 8, was later constructed. This was designed to permit immersion of a larger number of slides

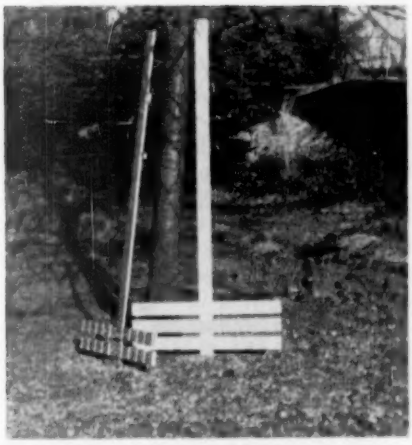

FIGURE 8.—Modified wooden holders for suspending large numbers of slides.

at a uniform depth at one location. The slides were mounted on wooden cross pieces attached to the vertical support rather than on the vertical support itself.

Test Plate Immersion

In order to permit the exposure of surfaces of different types and of larger areas, special test plates were used for some field experiments—either in conjunction with, or in place of, microscope slides. The test plates permitted studies of the effect of various types of surfaces, as well as comparison of the larger surface area of glass plates with the surface of microscope slides. The surfaces employed included glass and various construction materials (concrete, Transite and glazed tile). Plates of standard concrete, with and without coatings, and special antibacterial concretes were also studied.

Initially, test plates were immersed in sewers. Test plates of glass, concrete, glazed tile and Transite were employed in these studies. The amount of suspended solids collected on the apparatus was so great that test plates were found to be obstructed. The apparatus was then moved from the sewer to an open channel at the Plainfield (N. J.) Joint Meeting Sewage Treatment Plant, but obstruction in the comminuted raw sewage channel was still great (Figure 9).

The test panels were then moved to a settled sewage channel at the same plant. Very little obstruction occurred in the settled sewage channel, and this location was considered practical for further study. All test plate data reported were obtained from immersion in this channel.

The glass, glazed tile, concrete and Transite test plates were all 4-in. × 4-in. in size. Glass plates were cut from standard double strength window glass, and the Transite panels from a standard sheet of Transite. White, glazed tile plates were those commercially available. The 4-in. × 4-in. concrete plates were prepared according to specifications recommended by the Portland Cement Association (A.S.T.M. Spec. C109-49, hydraulic cement mortar). The concrete was poured into wooden forms, and two wires were imbedded in each plate for reinforcement and attachment. Con-

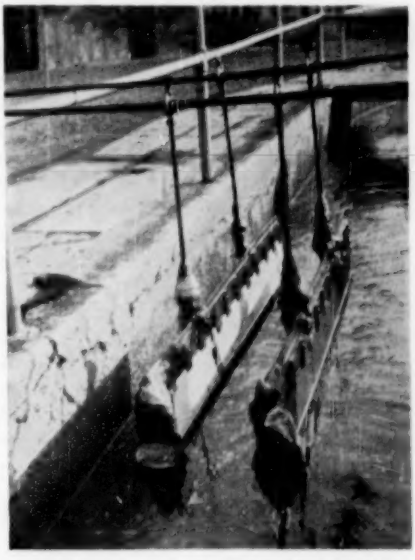

FIGURE 9.—Installation of test plates in raw sewage channel, illustrating solids collected after 20 hr. immersion.

FIGURE 10.—Unit-area sampler, test plate and sampling equipment.

crete plates were kept moist in the forms for 24 hours at room temperature (65° F.), then were removed and cured by submerging in tap water for 3 days. Water was changed daily during curing. The surfaces of all plates were finished with a Carborundum mason's block, wire brushed and washed.

Three sets of plates were supported in six racks. These racks were constructed of concrete reinforcing rod welded in the form of two A-frame end pieces connected by a series of parallel, horizontal rods. The racks formed a stand for support during immersion of the plates, and also for support of the plates removed for sampling. The A-frame end pieces served as handles in inserting or removing racks. Plates were secured to the racks by means of the wires imbedded in the concrete. The assembled racks were immersed in the open effluent channel carrying settled sewage from the primary clarifiers at the Plainfield (N. J.) Joint Meeting Sewage Treatment Plant.

Test plates of each type were sampled at weekly intervals for a period of 6 weeks. A special unit area sampler (10-cm. × 10-cm.) was constructed of sheet brass as illustrated in Figure 10. This was placed on the surface of the plate being sampled, and the slime was scraped into a bottle, using a soft rubber scraper. The test surface, scraper and sampler were rinsed with distilled water by means of a plastic wash bottle and the rinse water was collected in the sample bottle.

At the plant laboratory, samples were transferred to weighed dishes, dried over night in an oven at 105° C., cooled in a desiccator, and weighed.

Summary

Methods were developed to study slime formation in polluted waters under laboratory and field conditions.

The laboratory methods consisted of submerging microscope slides: (a) under static conditions, without the movement of either the substrate or the submerged surface; (b) with exposed air lift recirculation, inducing movement of the substrate over the contact surface suspended above the surface of the substrate; (c) using submerged air lift recirculation, in which the contact surface was entirely submerged under the surface of the liquid, and in which motion of the substrate was created by the air lift principle; (d) by alternate dipping and exposure, in which the slide surface was alternately dipped into the substrate and exposed to the air; and (e) employing a tank recirculation method, with static contact surfaces and inducing circulation of the substrate by means of a stirrer.

For studies under field conditions, various devices were developed. These included equipment for assembling and holding the microscope slides and test plates, for submerging the assembly in conduits carrying sewage and effluents, and a special unit area sampler.

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A CONSTANT TEMPERATURE TANK FOR FISH BIOASSAY AQUARIA

By Charles M. Weiss

*Medical Laboratories, Army Chemical Center, Md.**

Fish bioassay has become particularly significant with the increase in pollution abatement programs and the necessity for establishing toxic limits for many chemical products that may be discharged into waterways containing fish life (1)(2)(3). Laboratory bioassay of toxic chemicals, under critical temperature control, may enable the establishment of variable toxic limits depending on the temperature of the receiving body of water. Studies of this type require a constant temperature bath flexible in adjustment through a fairly wide temperature range, and easily controlled within 0.1° C. of the desired temperature.

The constant temperature tank described here was designed for the purpose of evaluating under a variety of temperature conditions the toxicity of certain chemicals that might be introduced into water and which would be detectable by fish bioassay. The size and shape of the tank was limited by the space available in the laboratory.

The particular feature of this constant temperature bioassay tank is that it is designed to hold fourteen, 12-in. × 12-in., circular glass aquaria, each calibrated to hold 15 l. of water. The 200-gal. tank is placed on a laboratory bench and occupies an over-all length of only 108 in. and is 37½ in. wide and 15 in. high. The aquaria are arranged in two rows of seven each (Figure 1). Each aquarium is raised off the tank bottom by the use of 1½-in. wooden cleats extending only the diameter of the aquarium.

Modifications of this design to accommodate more or fewer aquaria can be done simply by extending or shortening the tank. The temperature controls and water circulation system would probably require no change or modification for use in a tank with only 8 aquaria or as many as 16 or 18 aquaria. A four- or six-aquaria tank would probably require only one circulating pump and a smaller immersion heater.

A cross section of the tank is shown in Figure 2. The dimensions are not critical, clearances and spacings were chosen to keep the size to a minimum. Cypress sheathing is used for the interior tank surfaces that are in contact with the water. The outer sheath-

FIGURE 1.—Constant temperature tank for fish bioassay. Top view shows immersion heater, cooling pipe fins, circulating pumps and general construction features. Bottom view shows arrangement of aquaria with plastic covers.

* Present address; Department of Sanitary Engineering, School of Public Health, University of North Carolina, Chapel Hill, N. C.

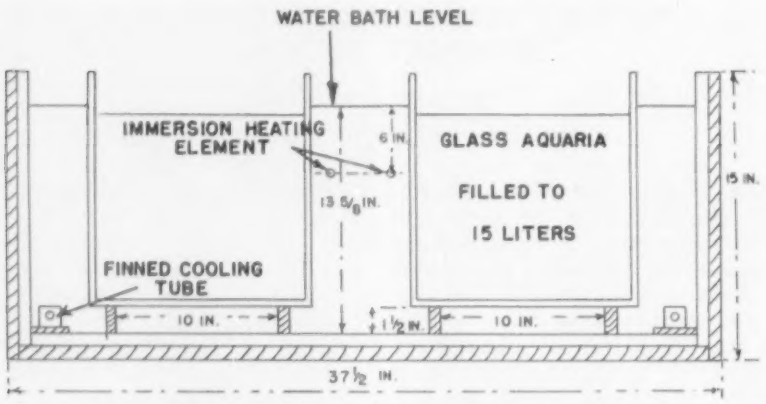

FIGURE 2.—Cross section of the bioassay tank.

ing is ¾-in. plywood. Four tie rods brace the tank laterally.

The flexible immersion heater is hung in the center of the tank from the bracing rods and the finned cooling pipes are laid along both sides the length of the tank (Figure 1). The cooling pipes are set on blocks which raise them slightly above the tank bottom. These pipes are connected together at one end with a ⅝-in. copper pipe. The intake and overflow lines of the cooling pipes are run up and over the edge of the tank. There are no subsurface breaks in the sheathing for the passage of pipes or wires.

Watertight integrity of the wooden tank was obtained by screwing pieces of quarter round in the corners. The surfaces of the wood were given several coats of varnish. After the first filling with water several small leaks developed but soon disappeared when the wood swelled.

The addition of a neon pilot light to the control circuit of the electronic relay provides a means for making a visible check on the operation of the bi-metal thermo regulator. Since the constant temperature feature depends on balancing heat loss by heat input, the on-off flicker of the pilot light indicates that at the particular temperature setting the controls are functioning satisfactorily.

The two centrifugal stirrers located in opposite corners of the tank provide the necessary circulation and mixing of the tank water. The stirrers draw the water up from the tank bottom and discharge down the length of the tank. The estimated circulation capacity of 105 g.p.m. for each stirrer, plus the deflection of the water by the round aquaria, assure a high degree of mixing and temperature uniformity throughout the tank. With the 14 aquaria in place, and correcting for the volume occupied by the aquaria and other underwater fixtures, there is actually only about 105 gal. of water that is being circulated by the stirrers.

The 1,000-watt heater is considerably larger than needed to maintain the tank at normal room temperature. However, it is helpful to have this extra capacity when it is desired to raise the temperature of the cold water rapidly to the operating temperature. For example, a typical operating procedure may have one 24-hr. bioassay exposure terminating in the morning. Refilling the aquaria with fresh colder water means a wait until the system is raised to the desired exposure temperature. On one occasion water having a temperature of 19° C. was used to refill the 14 aquaria. The bath temperature had been 24° C. and another bioassay run was started that same day. Heat transfer between the tank and water in the aquaria can

be sped up on such occasions by stirring the aquaria water approximately every 15 minutes.

Heat input to the bath is obtained from the immersion heater. The bath is cooled by running cold water from the laboratory water supply through the finned cooling pipe. The radiating capacity of this material is remarkably high and very efficient cooling is obtained. Operating the bath at a temperature of 24° C. requires only a trickle of 11° C. water flowing through the cooling system to balance the input of the heater. Under these conditions the pilot light flicks on and off about once every second. Operating the bath at a temperature of 12° C., which would be 12° C. to 13° C. below room temperature, requires increasing the water flow to reduce the tank temperature. When the new temperature is reached the thermostat is reset until the heat input is balanced by the cooling, as indicated by the flicker of the relay pilot light.

The lower temperature limit at which the tank can be operated is dependent on the temperature of the cooling water. In some areas of the country, particularly where the water may come from a surface water supply, tank operation would become impossible when the temperature of the cooling water supply increased above the desired operating temperature. This may be a significant limitation for two to four months of the year, depending on the annual temperature fluctuation of the local water supply.

If a more dependable operating schedule is desired for warm weather operation, a supply of cold water can be provided for circulation through the cooling line. This can be arranged by using a 50-gal. drum or similar container as a reservoir of cold water. A small centrifugal circulating pump can be used to circulate the cold water through the cooling line. The volume of flow into the finned cooling tube could be regulated by a by-pass line diverting part of the flow back to the reservoir or by adjusting the pump speed with a variable voltage regulator. The necessary volume and flow of cooling water would also be dependent on the difference in temperature between the operating temperature of the tank and the room temperature.

During short periods of operation (6–8 hr.) the water may be cooled with ice and the flow of cooling water adjusted as the ice melts. For longer operating periods (24 hr. or more) it may be more feasible to use a small refrigeration unit to reduce the temperature of the cold water supply. If the refrigeration unit is set to hold the temperature of the cold water supply at about 10° C. below that of the tank temperature, the volume of the circulating cold water can be kept to a minimum.

One feature of this tank is the ease with which the aquaria are readily removed for change of water and cleaning. Lifting the filled aquaria from the bath is unnecessary. A length of hose is used to siphon the aquaria to any convenient floor drain. As the water is removed from the aquaria they float to the surface and are easily lifted out. In filling, the aquaria are floated into position in the tank and then filled by pumping water from the storage tanks.

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THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

SMALL–TOWN OPERATOR

Successful operation of the larger sewage treatment plants frequently overshades the humdrum operation of the small-town facility. However, each satisfactorily operating treatment facility (large or small) is playing an important part in protecting the community health.

But here the similarity frequently stops. All too often the small-town sewage plant operator wears many hats. Superintendent of utilities, all the utilities and municipal services of the community, is frequently the all-inclusive title of this city employee. As a result, the sometimes unpleasant task of attending to the elemental functions of the sewage treatment process and equipment is badly neglected.

But what can be expected when there are a dozen demands on the operator's every hour. It is no 8-hr. day 5-day week that the small-town "jack-of-all-utilities" puts in. The recent survey of Iowa Operators (presented elsewhere in THIS CORNER) reveals that the small-town operators work 50 to 54 hours per week, often 7 days a week. Often the operator who endeavors to keep the treatment facilities operating must rely on his own material resources to do the job.

For this responsibility and effort he is rewarded with an average of $1.00 per hour. The small-town operator does not know the meaning of such taken-for-granted "fringe benefits" as paid vacation or sick leave. Under these conditions, the small-town operator deserves a medal for staying on the job at all.

In this age of the 40-hr. week, paid vacations, sick leave and other benefits the comments of these operators make unsatisfactory reading. Compared with the small-town operator the personnel of the Racine, Wis. sewage treatment plant (pop. 75,000) are quite fortunate (See "Interesting Extracts," This Corner). Even these operators, however, receive less than the prevailing average wage for skilled craftsmen in the building trades.

The Iowa Operators' Survey has performed a real service, not only in adding data on salary and working conditions to the record, but by focusing attention on the plight of the small-town sewage treatment plant operator. The problem is a serious one.

We have talked professionalism, and urged Member Associations to improve the status of the operator. Isn't it just as important for all members of the profession to aid each other? Even as the operating profession aids the least of its members, so does it benefit itself! D. P. S.

1955 SALARY SURVEY OF IOWA SEWAGE WORKS PERSONNEL

By Harris F. Seidel

Superintendent, Water and Sewage Treatment, Ames, Iowa

In the last four years, the Iowa Sewage Works Association has initiated and successfully developed both a voluntary certification program and a basic training program for sewage works operators. As a natural outgrowth of the interest stimulated by these programs a salary survey was made to determine the present salaries and working conditions of Iowa operators.

The first step was a study of all previous salary surveys reported in the literature (1) (2) (3) (4). Much was learned by reviewing the methods used and the results obtained by others.

Survey

A survey form was prepared and tested on the employees of several plants; it was also reviewed by the Association's officers. After many changes, to remove complicated and ambiguous questions, the survey forms were mailed in February, 1955. Reminders were mailed in March and again in July to help increase the number of returns.

A return of 43 per cent from the 290 treatment plants canvassed was most gratifying. This was particularly good considering that 162 facilities were operated by men who managed many or all of the municipal chores in towns serving fewer than 1,500 people. Response in this group was 24 per cent.

Classification of Returns

The next problem was how to separate or combine the returns for a fair comparison. Should it be based strictly on plant grade, size of city, or neither one? The smaller towns presented an additional problem because in some the treatment plants have a full-time operator while others get only part-time attention from a city employee who may also be responsible for water, streets, etc.

The final classification was a compromise, as follows:

Grade I plants, 8 or more employees.
Grade I plants, 2 to 5 employees.
Grade II plants, 5,000 to 10,000 population.
Grade II and III plants, 2,000 to 5,000 population (part-time operators separated from full-time operators).
Grade III and IV plants, 1,000 to 2,000 population (part-time operators separated from full-time operators).
Grade III and IV plants, under 1,000 population.

These groups do not include every situation, but cover almost all the plants replying to the survey.

This classification corresponds to the grades of sewage treatment plants under the Iowa voluntary certification program. Each grade is based on the population equivalent served and the degree of treatment. Grade I includes all plants, regardless of degree of treatment, having a population equivalent of 30,000 or more, or a secondary treatment plant having a population equivalent of 15,000. Other grades have a correspondingly smaller population equivalent. Considering connected population only, few Iowa cities are large, but in terms of population equivalent there are several large facilities.

TABLE I.—Iowa Sewage Treatment Training and Salary—Grade I Plants with 8 or More Employees

Classification	Returns (No.)	Education (Yr.)	Experience (Yr.)		Vol. Cert.	Salary ($)	
			Field	Job		Annual	Hourly
Superintendent	8	14½	14	7	all	5,610	2.64
Asst. supt. (Chief operator)	2	14	7	4	all	4,805	2.40
Chief mechanic	8	10	11	10	2 of 8	4,160	1.94
Shift operator	8	10	8	7	1/3	3,850	1.77
Lab. tech.	4	14	6	5	2 of 4	3,790	1.77
Mech. helper	6	12	6	2	2 of 6	3,700	1.73
Laborer	6	8	—	—	—	3,430	1.64

Salaries

For the large Grade I plants, a set of job descriptions was included with each survey form. It was believed that a salary comparison for such jobs as chief mechanic or shift operator would be useful only if based on a fair comparison of the duties and responsibilities. The job descriptions used are given in the Appendix I.

Average salaries and other information for personnel of the large sewage treatment plants are summarized in Table I. For most jobs, the salary paid in various cities is surprisingly consistent. The exception is the position of superintendent which varies more than $2,200.

The hourly rates shown are also averages, reflecting actual working hours. For example, if an operator reported an annual salary of $4,000 together with a 40-hr. work week and two weeks vacation, he was credited with 50 weeks × 40 hr. = 2,000 hr., and his hourly rate was calculated as $2.00.

Salary returns and other information for personnel of all other sewage treatment plants are summarized in Table II. As might be expected, sala-

TABLE II.—Training and Salary—Iowa Sewage Treatment Plants

Grade	Returns (No.)	Education (Yr.)	Experience (Yr.)		Vol. Cert.	Salary ($)		Work Week (Hr.)
			Field	Job		Annual	Hourly	
Grade I. 8 or more employees (shift operators)	8	10	8	7	1/3	3,850	1.77	44
Grade I. 2 to 5 employees								
Supt.	5	11	17	13	4 of 5	4,080	1.69	48
Principal operator	5	9	6	6	1 of 5	3,650	1.46	48
Grade II. 5,000 to 10,000 pop.	13	10	10	9	6 of 13	3,460	1.45	48
Grades II. and III. 2,000 to 5,000 pop.								
Full-time	15	9	6	6	5 of 15	3,020	1.22	50
Part-time	11	10	9	8	4 of 11	3,300	1.33	49
Grades III. and IV. 1,000 to 2,000 pop.								
Full-time	5	8	5	5	2 of 5	2,540	0.97	54
Part-time	26	10	6	6	7 of 26	3,280	1.25	52
Grades III. and IV. Less than 1,000 pop.	32	10	5	5	7 of 32	3,220	1.22	53

ries are lower for the small towns and small treatment plants. The comparison suffers even more from the fact that the small-town operator puts in 50 to 54 hr. a week, rather than the 44 hr. which is the average for the Grade I shift operator.

Probably the most striking revelation of this survey is the low status of full-time sewage plant operators in small towns, in comparison with general employees in similar towns who have a variety of jobs to perform (sewage, water, streets, etc.). Full-time plant operators in towns of 1,000 to 2,000 and 2,000 to 5,000 populations are paid an average of $212 and $252 per month, respectively, while the part-time operators in similar towns are paid an average of $275 per month. Far from being classed as a "specialist," the small sewage treatment plant operator occupies absolute bottom rung on the salary ladder. This salary comparison speaks louder than words in regard to the problems of small-town sewage treatment plant operation.

Fringe Benefits

By fringe benefits is meant such "extras" as paid vacations and holidays, sick leave provisions and payment for overtime or other emergency work. In Grade I plants, the two-week vacation, 6 to 8 holidays per year and accumulative sick leave are standard benefits. In addition, most of the men below the supervisory level receive either extra pay or compensatory time for overtime work.

For the small-town plant operator, the chances are no better than even that any or all of these are provided. This information is summarized for all sewage treatment plants in Table III.

Working Conditions

In this age of the 40-hr. work week and overtime for industrial workers it is sobering to take a closer look at the position of the small-town sewage treatment plant operator.

"I work 6 days a week, 9 to 10 hours a day. I am off Sunday except for about 2 hours at the disposal plant.

"In addition to operating the sewage plant I take care of the streets, park, water, municipal building janitor, city dump and city marshal. A steady job for the whole year, 7 days a week. Sundays I just pump water, but it keeps you pretty close to home. Can't leave Saturday night and come back Monday morning.

"I am the operator of both water and sewage systems. I take care of both plants on Sundays and holidays as well as week days. I have a helper 3 days a week. I am on call 24 hours a day. Any time left is mine. I get one week's vacation a year."

For the effort and responsibility, what does the operator receive? In towns under 2,000 population, it is likely as not that he is receiving less than $1.25 per hour. In fact, 7 returns showed salaries amounting to less than $1.00 per hour. Even in towns up to 5,000 population, chances are less than even that any payment (money or time off) is granted for overtime work, and about 1 in 10 that overtime is paid for in cash. Vacation policies are poor; one man reported receiving neither vacation time nor holidays for 17 years. Sick leave may or may not be granted when needed. Under these conditions, the small-town operator deserves a medal for staying on the job at all.

Comparison With Other Surveys

Ohio—1953

In 1953 the Ohio Conference made a careful survey of full-time operator salaries, following an excellent study of the qualifications, duties and responsibilities of sewage works personnel. A study of the salary survey report (4) shows that, in general terms, shift operators in medium-sized Ohio sewage treatment plants were even then receiving $200 to $500 per year more than is now being paid for correspond-

TABLE III.—Benefits and Activities—Iowa Sewage Treatment Plants

	Returns (No.)	Paid Vacation			Paid Holidays		Overtime Payment			Sick Leave (Days per Year)	Member I.S.W.A.	Make Regular Lab. Tests	Make Regular Plant Reports
		2 Wk.	1 Wk.	None	Usual (6–8)	None	Time	Money	None				
Grade I. 8 or more employees	8	all[1]	—	—	all	—	4	3	1	Av. 15 (accumulate 85)	all	7 of 8	7 of 8
Grade I. 2 to 5 employees	5	all[2]	—	—	4	1	2	2	1	Av. 8 (accumulate 25)	all	all	4 of 5
Grade II. 5,000 to 10,000 pop.	13	11	1	1	10	3	3	—	10	9: 5–12[2] 4: nothing	7 of 13	9 of 13	3 of 13
Grades II. and III. 2,000 to 5,000 pop.													
Full-time	15	12	1	—	7	6	7	1	5	11 of 14[2]	6 of 13	11 of 13	2 of 13
Part-time	11	6	5	—	6	5	3	2	6	9 of 11	9 of 11	3 of 11	5 of 11
Grades III. and IV. 1,000 to 2,000 pop.													
Full-time	5	4	1	—	all	—	2	—	3	2 of 5	3 of 5	2 of 5	2 of 5
Part-time	26	13	6	6	14	10	6	2	10	12 of 24	9 of 25	5 of 25	9 of 25
Grades III. and IV. Less than 1,000 pop.	32	12	5	10	11	13	6	1	17	10 of 24	8 of 28	1 of 28	4 of 29

[1] Some receive 3 weeks vacation after 10, 15, or 20 years service.
[2] Sick leave seldom accumulated.
[3] Sick leave usually granted informally; no definite rules.

TABLE IV.—Relative Pay Scales*

Position	Penn. 1950[1]	Iowa 1955[2]
Supt.	1.61	1.46
Chief Operator	1.22	1.25
Chemist	1.26	—[3]
Chief Mech.	1.20	1.08
Operator-Mech.	1.05	—
Shift Operator	1.00	1.00
Mech. Helper	—	.96
Lab. Tech.	.83	—[3]
Laborer	.85	.89

* Based on shift operator as the median.

[1] Adapted from median salaries, Table VI in published report (1).

[2] Adapted from median salaries, Grade I plants.

[3] On this scale, the Iowa Chemist-Lab. Tech. rates 0.98.

ing jobs in Iowa. In the larger plants, however, Ohio 1953 and Iowa 1955 salaries for most jobs were the same or nearly so, except that the Iowa plant superintendent is somewhat better paid.

Pennsylvania—1950

Another valuable survey was conducted by the Pennsylvania Association in 1950 (1). Returns were received from 60 plants in and near Pennsylvania corresponding generally in size to Iowa Grade I plants. No salary comparisons are made because of the time elapsed, but it is particularly interesting to note the relative pay for the different positions (Table IV), and to compare the scales derived from the two surveys.

Iowa—1951

Of passing interest is a hasty survey of the larger Iowa plants made in 1951. A comparison over the four-year period shows that shift operators have had salary increases averaging 23 per cent and chief mechanics 18 per cent, while superintendents as a group have advanced only 13 per cent in salary. During this same period, wages paid to construction laborers and skilled craftsmen (3 trades) advanced 25 per cent and 23 per cent, respectively, according to the *Engineering News-Record* index trends for the country as a whole.

Comparison With Other Jobs and Skills

A salary survey is always open to the question: what is being paid for comparable work in other occupations? In an effort to provide an answer, a second survey was made of representative jobs and skills of various skilled crafts in Iowa.

Crafts Survey

Questionnaires requesting current wage rates for 8 occupations were sent to the state employment service offices in 15 Iowa cities. In addition to crafts such as plumber and carpenter, an attempt was made to gather data on jobs which could be considered at least related to the duties of a sewage plant operator or mechanic.

The 15 cities were selected for the best possible geographical distribution across Iowa. Of those surveyed, 12 are in the population range of 20,000 to 90,000. A study of the results, which were quite complete, indicated that the size of the city had little effect on wage rates. While certain jobs paid 10 to 15 cents per hour more in the larger cities, others rated as well or even higher in the smaller cities.

TABLE V.—Wage Rates in 15 Representative Iowa Cities

Job Title	Union ($ per hour)		Non-Union ($ per hour)	
	Average	Typical Range	Average	Typical Range
Plumber	2.82	2.70–3.00	1.98	1.50–2.50
Pl. Helper	1.86	1.70–2.00	1.50	1.25–1.75
Electrician	2.70	2.00–3.00	1.94	1.50–2.50
Carpenter	2.61	2.50–2.80	1.94	1.50–2.50
Laborer—Const.	1.97	1.80–2.15	1.42	1.00–1.75
Maint. Mech. II.[1]	2.04	1.70–2.15	1.64	1.50–2.00
Meter Reader[2]	1.86	1.45–1.80	1.43	1.20–1.75
Laborer—W. Wks.[3]	1.63	1.40–1.80	1.36	1.00–1.50

[1] Corresponds to position of chief mechanic.

[2] Typical utility meter reader.

[3] Unskilled labor under supervision.

Results

The results of this survey are presented in Table V. At the suggestion of the state employment service, both union and non-union rates were considered. The significance of this varies with each community. Where union influence is slight, few workmen are benefited by the union wage scale. On the other hand, in strongly unionized cities even non-union men, if competent, draw pay at or near union scale.

In general, it was felt that this survey provided a valid basis for certain comparisons. Iowa sewage works employees live and work in and near the cities surveyed; they are aware of the union wage scales. As a result the job attitudes, as well as the possibilities of attracting capable men for new openings, are bound to be influenced by these conditions.

ASCE Survey—1955

Earlier in 1955 the American Society of Civil Engineers published (5) the results of a salary survey concerned primarily with civil engineering positions. For comparison, however, the following data were presented on average union wage rates across the country for certain crafts.

Trade	Hourly Rate
Plumbers	$3.15
Electricians	3.13
Carpenters	2.94
Plasterers	3.30
Brick layers	3.42

As might be expected, these rates are 30 to 40 cents per hour above the union scale for the same trades in Iowa; yet the pattern is similar. Average union rates for plasterers and bricklayers are one-third more than the average Iowa Grade I sewage plant superintendent receives, and twice what the shift operators earn. Average work week for the building craftsmen is 36 to 40 hr.

Summary

One critical problem apparent in the Iowa salary survey returns was the small spread in salary between the top positions and the routine jobs. Surely the training, effort and responsibility required of a superintendent of a large sewage treatment plant rates a higher salary.

The New England Sewage and Industrial Wastes Association (6) has given serious consideration to the classification and licensing of sewage works personnel, culminating in 1946 with a schedule of suggested minimum salaries and recommendations for keeping pace with the rising living costs. In 1947, a report was made to the California Sewage and Industrial Wastes Association (7) on an extensive job classification and salary survey project conducted by the City of Los Angeles. This report provided a wealth of information on job and salary ratings for both sewer maintenance and sewage treatment plant employees.

When properly done, job study and evaluation have much to offer sewage treatment plant personnel. For one Iowa plant, city-wide job classification was largely responsible for a 40 to 55 per cent pay increase from 1951 to 1955. As a result, these jobs are on a par with equivalent water and electric utility positions; something so unusual as to be worth reporting.

Conclusion

Successful sewage treatment operation involves more than long hours and a strong back; it involves at least a general understanding of mechanical equipment, of simple bacteriology and chemistry and the ability to keep records.

Successful operation of the larger sewage treatment plants is taken almost for granted now. There is always room for improvement in both the ability and the pay of men in these plants, but such improvement has been steady in recent years.

For the very small treatment plants, the problem is different. Many plants

receive attention only one or two hours a day from a man who is poorly trained, poorly paid, and too busy with six other jobs to be interested. It has been said: "You can't get a good man for that money; and you can't raise the pay until you find a better man for the job."

On the whole the sewage works salaries of Iowa operators are painfully low. They are less than the salaries received by any other group of municipal employees and are below those received by any other employment group.

Acknowledgment

Appreciation is expressed to every Iowa sewage works operator who took part in the survey; and particularly to Dominic Morrow, a senior shift operator at the Des Moines sewage treatment plant, for his suggestion leading to the survey of wage rates for other jobs and skills.

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APPENDIX I—JOB DESCRIPTIONS GRADE I IOWA SEWAGE TREATMENT PLANTS

Superintendent—In responsible charge of the sewage treatment plant.

Assistant Superintendent or Chief Operator—In charge of shift operators and maintenance crew. Reports directly to the superintendent, is responsible for work as planned. He does not take an 8-hr. operating shift, but does some work with the operators, some with the maintenance crew; may do some laboratory work or some work on records.

Chief Mechanic or Maintenance Foreman—Responsible for all maintenance and repair projects. This is a skilled job requiring training in a sewage treatment plant or experience in another job.

Shift Operator—Responsible for plant operation on an 8-hr. shift. He may report directly to the chief operator or to the superintendent. Normally he has no one working under him (except in the larger plants) and does little maintenance work.

Chemist or Laboratory Technician—A skilled job requiring training in sewage-laboratory techniques. This man normally reports to the superintendent and usually has no one working under him. Usually in charge of the laboratory and does no operating or maintenance work.

Mechanic's Helper or Maintenance Man—Works with and reports to the chief mechanic. The job is semi-skilled and provides training. Activities include a variety of odd jobs and some operating, but he is rated above a laborer or helper.

Laborer or General Helper—May work with and report to various other men in the treatment plant. The job is unskilled and requires little or no training or experience. The responsibility is limited.

A DOUBLE DUTY OXIDATION POND

By Edward O. Sampson

Chief Operator, Sewage Treatment Plant, Oceanside, Calif.

The 2.0 m.g.d. Oceanside Sewage Treatment Plant was designed to provide intermediate sewage treatment using primary and secondary oxidators in series. After two years of experimenting operation reverted to simple primary sedimentation with separate digestion (1).

Previous to the construction of the new sewage treatment plant in 1950, the treatment facilities consisted of a septic tank with two compartments, and an ocean outfall sewer 2,700 ft. long. The 12-in. cast iron outfall had 2,000 ft. submerged offshore, with the diffuser located 35 ft. below the water surface. This outfall line and septic tank were incorporated in the plans for the new plant. The septic tank acted as a surge tank of 90,000 gal. capacity during periods when the outfall sewer was overloaded. A break in the outfall at about 60 ft. offshore increased the apparent capacity to 1.5 m.g.d.

The initial population served was 12,000 with a flow of 0.8 to 0.9 m.g.d., however, within four years the rapid population growth raised this to about 20,000, with the summer influx of tourists increasing this to 23,000. The flow averages 1.6 m.g.d. with peaks of 1.8 m.g.d. in the summer.

Early in 1954 it was obvious that the summer flows would be greater than the septic tank and outfall sewer could accommodate, and that relief would be needed when high tides coincided with peak flows. A natural estuary, immediately adjacent to the plant, was studied with the thought of using part of it as a temporary oxidation pond. This pond would provide storage for excess flow during the peak flow periods.

A second use of the proposed pond would be to furnish a supply of water with a high dissolved oxygen content to recirculate through the treatment plant. Mixed with the influent sewage the recirculated pond water would provide a source of oxygen useful in reducing odors in the treatment plant and reducing the prechlorination requirements.

Odor control had been a prime consideration since the plant was placed in operation. The treatment site is located only 200 yd. from the ocean and within the city limits. Residences of 35 to 40 families are located within a radius of 500 yd. of the treatment plant.

Prechlorination requirements have been as high as 25 p.p.m. of chlorine with an additional 10 to 12 p.p.m. used in postchlorination for sterilization. Any reduction in this amount would be a distinct saving in operation costs.

Pond Construction

The natural topography was such that a five acre pond could be constructed with a minimum length of artificial dikes. (Figure 1.) Dikes 4 to 5 ft. wide at the top, were constructed with a dragline at a cost of $1.50 per lineal foot. Only 825 ft. of dike were needed, of which 325 ft. made a baffle dike to prevent short circuiting within the pond. The average depth of the pond when full is 3.5 ft. with a depth of 2 ft., minimum and a maximum depth to 6 ft. next to the channel of the estuary.

The existing raw sewage lift station on the edge of the pond was to be utilized for returning pond effluent to the treatment plant influent. The pond surface level was sufficiently high to permit gravity flow over a 12-in. straight edge weir into the wet well. A control gate on the weir box was installed to regulate the flow. The mix-

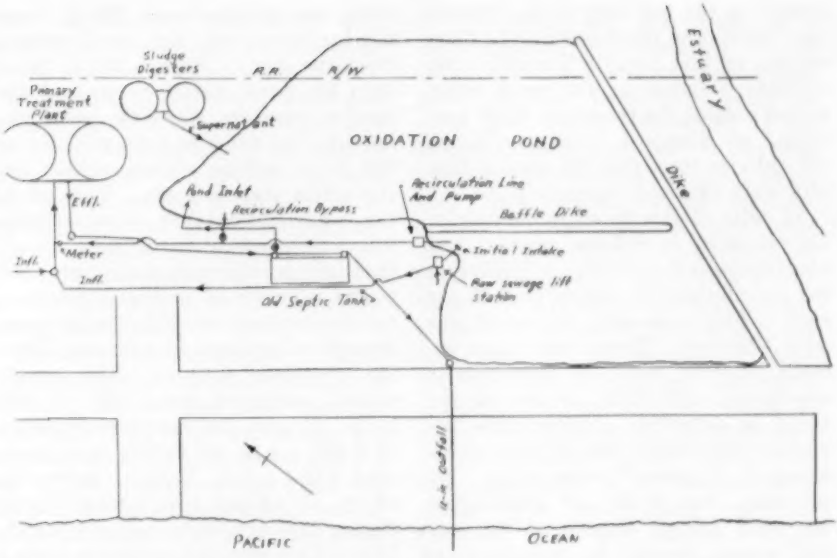

FIGURE 1.—Sketch of oxidation pond and recirculation lines, sewage treatment plant, Oceanside, Calif.

ture of raw sewage from South Oceanside and pond effluent would then be pumped through a 6-in. force main to the interceptor just outside the treatment plant.

Construction of dikes and weir was completed on August 1, 1954. Filling the pond required three weeks to allow time for a good algae growth to get started. The pond was seeded with 15 drums of pond water from a sewage oxidation pond located 15 mi. south of Oceanside. The seed water was carefully selected to prevent the start of any blue-green algae which have caused serious difficulty in oxidation ponds in this area. Microscopic examination of the seed water revealed principally *Chlorella* with a few *Scenedesmus*. A small portion of the pond was filled, seeded and allowed to stand a week before adding additional primary effluent. As soon as D.O. tests showed a good oxygen content, more plant effluent was added until the pond was full and ready for recirculation.

Early Recirculation Experience

Actual circulation of pond effluent to the plant inlet was started the latter part of August, 1954 with varying degrees of success. It was soon determined that the pond loading limit could be easily exceeded, but the capacity of the lift station pumps was not sufficient to handle the desired increase in recirculation load. During peak flow periods (9 AM to 12 M and 6 to 9 PM) the lift station pumps could handle little more than the raw sewage flow. This limited the volume of pond effluent that could be added to the lift station wet well. However, the excess treatment plant effluent which was allowed to discharge to the pond could always be pumped out at night when the raw sewage flow was low. This accomplished the desired reduction in load on the outfall sewer during peak flow periods.

Another disadvantage to this system was the fact that mixing pond effluent, having a high D.O. content, with raw

sewage in the wet well of the lift station resulted in the depletion of all the oxygen at that point. Therefore, the mixture arriving at the main interceptor outside the treatment plant contained no dissolved oxygen, although the sulfides from this lift station usually were oxidized completely.

In spite of this handicap, a definite improvement in influent sulfides was observed and the chlorine consumption for prechlorination was reduced 15 per cent. This naturally improved the odor situation. There were some periods, however, when the pond became overloaded and little or no oxygen could be detected. During these periods recirculation was of little value except to dispose of excess water. No provision was made for discharging the pond effluent directly to the outfall sewer, except by returning it through the plant and thence to the outfall.

On one occasion, shortly after starting up, the pond became septic due to overloading. Commercial sodium nitrate was obtained and 300 lb. were hand-scattered on the pond surface from the shore. Within two or three days the pond started to revive. On another occasion, when the pond was inactive but not septic, an addition of 100 lb. of sodium nitrate quickly got the action started again. This led to the consideration that more nitrogen would be beneficial to the pond. Since the digester supernatant contained 300 p.p.m. or more of ammonia nitrogen, the supernatant was added to the pond through a separate line directly from the secondary digester. This supernatant contained from 320 to 360 p.p.m. B.O.D., an average alkalinity of 3,400 p.p.m. as $CaCO_3$, and averaged 6,000 g.p.d. Table I shows the effects of adding supernatant liquor during January, February and March, 1955. This was the healthiest period the pond has had to date. The addition of supernatant was discontinued later when it was thought too much load was being placed on the pond because of increased sewage flows.

TABLE I.—Summary of Oxidation Pond Operation

Month	Total Plant Flow (m.g.d.)	Recirc. Oxid. Pond, Effl. (m.g.d.)	Raw Sewage (m.g.d.)	B.O.D. Load (lb./acre/day)	D.O.[1] Pond. Effl. (p.p.m.)	Sulfides Infl.[2] Sewage (p.p.m.)	Chlorine[3] (lb./m.g.)	Supernatant Added (g.p.d.)
Sept. 1954	1.35	.092	1.26	27.6	—	.63	212[4]	—
Oct.	1.40	.187	1.21	35.4	—	.52	140[5]	—
Nov.	1.40	.133	1.27	24.2	—	.59	—	—
Dec.	1.39	.144	1.25	34.9	—	.47	—	—
Jan. 1955	1.48	.177	1.28	43.2	13.4	.26	—	4,310
Feb.	1.49	.164	1.33	38.2	14.5	.20	—	3,510
Mar.	1.55	.189	1.36	41.4	11.2	.26	—	5,010
Apr.	1.66	.183	1.48	44.0	3.7	.34	96[6]	—
May	1.73	.190	1.54	47.2	4.8	.44	95[7]	—
June	1.78	.178	1.60	43.1	6.2	.56	106[8]	2,030
July	1.86	.196	1.67	45.7	3.3	.73	181[8]	—
Aug.	1.95	.232	1.72	57.1	2.1	.80	220[8]	1,430
Sept.	1.88	.198	1.68	44.3	1.0	.85	221[8]	430
Av. 1955	1.71	.190	1.52	44.9	6.7	.5	—	2,786

[1] Determination made at 8 A.M.
[2] Combined total influent before chlorination.
[3] Based on raw sewage flow.
[4] 30 per cent used in post-chlorination.
[5] Prechlorination Oct. 1–9.
[6] Prechlorination entire month.
[7] Postchlorination started May 27.
[8] Includes pre- and post-chlorination.

Small amounts of supernatant were added to the pond in June and August, but no conclusive effect was noted.

Pond influent flow was not metered, but the effluent flow was measured over the weir. To determine pond loading a series of tests was established to compare the salt content of the pond influent and effluent. With this information an evaporation rate, varying from 11 to 16 percent, depending on the temperature and weather, was determined each month.

The volume recirculated to the plant inlet was used as a basis. To this was added an amount equal to the evaporation loss. From this total volume and the average B.O.D. of plant effluent, the B.O.D. loading of the pond was calculated. Loss from seepage was ignored, as it appeared to be negligible, based on frequent inspection of the dikes. The B.O.D. loading due to the supernatant was also included.

Separate Recirculating System

During the winter the pond proved to be of sufficient value in odor control to warrant additional investment in a separate pump and recirculation line. Accordingly, a 5 h.p. close-coupled pump having 200 g.p.m. capacity at a 50 ft. head was purchased. A new recirculating line was constructed of used asphalt coated 5-in. well casing, with mechanical joints. A reconditioned 3-in. water meter was installed on this line. The cost of this system was $950 and it was placed in operation on April 21, 1955.

Another improvement was to relocate the inlet to the pond 120 ft. north of the outfall bypass. The new inlet extended into the pond 12 ft. and was submerged one foot under the water surface. Originally the pond influent flowed through a short channel and then splashed down 2 to 3 ft. to the pond surface. The new arrangement removed another source of sewage odors.

The new recirculating system provided an increase in capacity up to 300,000 g.p.d., and now pond water supersaturated with dissolved oxygen could be blended with the raw sewage just upstream from the treatment plant inlet where full benefit of the oxygen could be obtained. It was soon learned, however, that the pond had a load limit beyond which septicity quickly resulted. It was hoped that loadings up to 50 lb. or even 60 lb. of B.O.D. per acre per day could be obtained. A safe maximum load now appears to be about 45 lb. per acre per day (Table I). Oxygen depletion during the hours of darkness was rapid, although D.O. contents as high as 35 p.p.m. were present in the pond effluent in the late afternoon. At 7:30 AM this value would be as low as 2 to 3 p.p.m. The recirculation was programmed to the D.O. content. Small flows (100 g.p.m.) were recirculated from 7:30 AM to 1:30 PM, with the full capacity of the pump (210 g.p.m.) utilized from 1:30 PM to 11:30 PM. Very little, if any, pond water was recirculated during the period from 11:30 PM to 7:30 AM. The volume depended on the sewage flow and the tides, which governed the amount of treatment plant effluent required to be discharged to the pond. The pump operated at full capacity 24 hr. per day and the pond effluent that did not go to the plant inlet was bled off the recirculation line back into the pond near the inlet. This provided seed for mixing with the primary treated sewage plant effluent going into the pond.

During the months of July through the middle of September, 1955, the outfall sewer was badly overloaded, especially when high tides coincided with peak flows. Consequently more primary effluent had to be by-passed to the pond than the pond could handle satisfactorily, resulting in overloading. The average morning D.O. content kept decreasing through these months, although the D.O. content in the afternoon was usually 12 p.p.m. or more. The loading could not be reduced until the latter part of September, when the

population load decreased at the end of the summer season. The pond did not actually become septic, although it threatened to do so on several occasions. Days with plenty of sunshine helped to prevent such a nuisance from occurring.

Mosquito Control

As soon as the pond was started, assistance from the San Diego County Department of Public Health, Mosquito Abatement Division, was requested. Thereafter the pond received regular inspection by their field men and was sprayed when necessary. In the first few weeks of operation the pond was sprayed heavily and frequently with a 5 per cent D.D.T. solution in diesel fuel oil. It was thought that the resulting oil film was hindering the algae growth, as evidenced by periods of septicity after heavy spraying. The toxicant was changed to a 1 per cent Lindane solution in water with a wetting agent. This mixture did not seem to harm the algae but it was less effective than D.D.T. in mosquito control.

Mosquito breeding decreased during the winter months, but never did stop completely. With the return of warm weather the pond became heavily infested with a gnat population in addition to the mosquitos, and the Lindane was ineffective. Again D.D.T. was used, with occasional sprayings with toxiphene; finally in September, 1955, breeding was controlled, and no further spraying was necessary. The algae successfully survived the oil spray this time.

Another aspect of mosquito control was the weed situation. Although the pond was too deep for any aquatic growth in the water, vegetation growing on the banks at the edge of the water and overhanging grasses and weeds provided perfect shelter for mosquito larvae and pupae. Accordingly, considerable labor was necessary to scrape the entire shoreline of the pond free from weeds. This proved quite effective in the control of mosquitos. In addition, weed killer was also used on the vegetation on the pond banks.

Stocking the pond with *gambusia affinis* for mosquito control proved to be of little value. A total of approximately 20,000 of these guppy type fish were added to the pond in three stockings. Very few fish were ever seen alive and dead ones occasionally were found. Gambusia are reputed to be avid consumers of mosquito larvae, but evidently they could not withstand the periods of low dissolved oxygen or else the pond water may have been too brackish for them. Gambusia are not effective on gnat larvae which grow in the bottom mud.

Observations

In the spring, when the water temperature in the pond increased to about 60° F., *daphnia moina*, were found in the pond. These crustaceans, measuring not more than 1/32 in. in length and having a reddish brown color, make excellent food for tropical fish.

During periods of low D.O. content or septicity, daphnia appeared on the surface of the pond in large numbers, enough at times to color the entire north half of the pond. Crustaceans are oxygen consumers and, in addition, feed on algae. They may have been a factor in the apparent poor performance of the pond. Daphnia were visible mostly in the early morning hours, but after a few hours of sunshine, when the oxygen content increased, they would scatter and submerge, to appear again the next morning. When the pond was in a healthy condition, *daphnia* were not observed, but they could be recovered by seining with a cheesecloth net. When the pond temperature rose above 80° F., these crustaceans disappeared until fall, when a new crop was hatched in cooler water.

Tubifex worms occasionally were seen in the bottom mud but presented no problem.

Summary and Conclusions

A five acre oxidation pond provided a place for the storage of primary sewage treatment plant effluent when the capacity of a 12-in. ocean outfall sewer was overloaded during peak flow periods. In a dual function the pond supplied effluent supersaturated with D.O. for recirculation, thereby decreasing the chlorine consumption and reducing odors. Recirculation rates varied from 12 to 14 per cent of the raw sewage flow. Oxidation pond capacity up to 45 lb. of B.O.D. per acre per day proved feasible. Had a larger oxidation pond area been available, a much higher recirculation rate could have been used, with the assurance that nuisance odors could be almost entirely eliminated.

The $2,500 cost of the dikes and recirculation system was repaid in 15 months through the saving in chlorine. As a surge tank, the pond provided relief for an overloaded ocean outfall until plans can be developed for more adequate disposal, either through a new ocean outfall or enlarged oxidation ponds. The small-scale pond provided fundamental data on which to base future operations.

Acknowledgment

The assistance and encouragement of Isadore Nusbaum, sanitary engineer, California Regional Water Pollution Control Board, Region 9, and the cooperation of the Mosquito Abatement Division of the San Diego County Department of Public Health is gratefully acknowledged. Mr. Richard Pomeroy, consulting engineer, also rendered valuable advice on the pond operation.

Reference

1. Sampson, E. O., "Sludge Digestion at Oceanside, California." THIS JOURNAL, **26**, 8, 1033 (Aug., 1954).

INTERESTING EXTRACTS FROM OPERATION REPORTS

"A determined man can do more with a rusty wrench than a loafer with all the tools in a machine shop."—Anon.

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Annual Report of the Racine, Wis., Sewage Treatment Plant for the Years 1953 and 1954 *

BY THOMAS T. HAY, *Superintendent*

The quantity of sewage treated has shown a gradual but important decrease during the years 1953 and 1954. Average flow in 1952 was 14.482 m.g.d., decreasing to 14.396 m.g.d. in 1953 and to 14.192 m.g.d. in 1954. The highest average daily flow was 21.285 m.g.d. in 1951. This reduction can be attributed to two factors: (a) the elimination of storm water from the combined sewer system and (b) the reduction of infiltration in the system

* For last previous extract see THIS JOURNAL, **25**, 12, 1463 (Dec., 1953).

as a result of the follow-up of the study of the sewer system made in the latter part of 1952.

Operating conditions were normal during these two years. This was very welcome after the erratic conditions of 1952 caused by the high water level in lake Michigan. Treatment results were good although activities of the expansion program caused some interruption to plant operations. Effects of this kind, however, were held to a minimum.

Construction Program

The most noteworthy development of 1953 was the action of the Racine Common Council in initiating a financial program for treatment plant and sewer system improvement and expansion. This is the first expansion of the treatment plant since it was put in operation in 1938. The work will be financed by the inclusion of approximately $200,000 in the budget for 1953 with the recommendation that the program be maintained for a three-year period.

New work planned in 1953 included the addition of a pump for lift station No. 1, electrical work on the other two lift stations, a 90-ft. diameter digester, sludge pumps, heat exchanger, bar screen, six glass-covered sludge drying beds; and other appurtenant work and controls. An appropriation of $200,000 was added in 1954 to the funds budgeted in 1953.

Financing without recourse to bonding is expected to save interest and other finance charges equal to nearly one-half the capital cost of the improvements.

Funds were not appropriated in the 1955 budget to continue the construction program. Reason for the decision to delay construction of additional clarifiers was that the extensive construction program of separating storm and sanitary sewers had resulted in a reduction of flow. Another reason was to await a study of the results obtained from experimental work with a flotation unit † for primary sewage treatment. The result of work over a period of several months demonstrated satisfactory solids removal and a more concentrated sludge could be obtained with flotation than with conventional methods.

Plant Operation

Although the raw sewage flow had been reduced, the present flow was still 120 per cent of the design capacity. The B.O.D. of the raw sewage was greater in 1953 than 1954, but this was due to a record rainfall during the latter year. However, the digester loading was high, averaging 12,100 lb. of solids (dry wt.) per day for the two-year period, or .095 lb. of solids per cubic foot of digester capacity per day.

The digester under construction will double the plant digester capacity. In connection with the construction program the three existing digesters were emptied in 1954. Construction work caused many interruptions of varying duration and required additional planning and work so that the treatment of sewage was not affected adversely. Digester operation was impaired by an accumulation of hair from tannery waste which necessitated 11 hosings to break-up the scum blanket. Cooperation by the tannery reduced the amount of hair received. Routine inspection and maintenance schedules were followed so that the equipment and structures received the attention necessary for good operation and maintenance. The problem caused by the waste water from the chlorinator carrying chlorine which was released in the pipe galley was rectified. New chains and sprockets were placed on the scrapers in clarifiers No. 1 and No. 4. Sections of the chain and sprockets were examined in the laboratory by the equipment manufacturer. A complete report was submitted.

Summary of the 1953 and 1954 operating data is given in Table I:

† Float-Treat system by Chain Belt Co.

TABLE I.—Summary of 1953 and 1954 Operation Data at the Racine, Wis., Sewage Treatment Plant

Item	Average 1953	1954
Total rainfall (in.)	17.64	36.15
Population:		
Connected	73,000	75,000
Equiv., B.O.D.	106,470	69,000
Equiv., susp. sol.	80,727	79,273
Sewage flow (m.g.d.)	14.396	14.192
Per cap. sewage flow (gal.)	197	194
Settling tank retention (hr.)	2.7	3.2
Total solids:		
Influent (p.p.m.)	594	724
Effluent (p.p.m.)	480	581
Reduction (%)	19	20
Settleable solids:		
Influent (ml. per liter)	3.86	3.80
Effluent (ml. per liter)	0.16	0.20
Reduction (%)	95	96
pH:		
Influent	7.54	7.79
Effluent	7.54	7.86
Suspended solids:		
Influent (p.p.m.)	145	140
Effluent (p.p.m.)	68	60
Reduction (%)	53	51
B.O.D., 5-day:		
Influent (p.p.m.)	145	98
Effluent (p.p.m.)	96	63
Reduction (%)	34	36
Chlorine demand:		
Raw (p.p.m.)	9.14	7.06
Effluent (p.p.m.)	8.90	6.80
Raw sludge to digesters:		
Gal. per day	25,851	26,107
Dry solids (%)	5.37	5.52
Dry solids (lb. per day)	11,791	12,443
Volatile solids (%)	62	59
pH	6.60	6.76
Digested sludge:		
Digested solids to beds (lb. per day)	2,199	2,423
Per cent solids	15.24	15.6
Volatile solids (%)	39	37
pH	6.92	7.03
Supernatant solids (%)	0.87	0.98
Analysis of dry sludge (%):		
N	3.67	3.34
P_2O_5	2.52	2.98
K_2O	0.44	0.47
Grease	3.55	5.12
Humus	39	36
Moisture	31	38
Gas, cu. ft. per capita per day	0.659	0.578
Gas, cu. ft. per lb. vol.	6.58	6.38
B.t.u.	656	657
Oxygen (%)	1.2	1.2
Nitrogen (%)	1.4	1.5
Hydrogen (%)	1.4	1.4
Carbon dioxide (%)	31	31
Methane (%)	65	65
Operating costs ($):		
Total	95,875.15	103,844.34
Per capita	1.31	1.423
Per m.g.	20.05	18.49

Operating Personnel

In 1954, four new men were placed on the staff and required training. Two men replaced staff losses due to a death and a retirement. An additional operator and a mechanic's helper were necessary through a reduction in the work week from 44 hr. to 40 hr. The operating staff now consists of two mechanics and helpers, five utility men and six operators including a relief operator. Supervision is supplied by an engineer and a chemist.

For the preceding 8 years there had been no turnover of personnel. Each operator is given an opportunity to attend the short school and various operators' meetings on a rotation basis.

Personnel worked the following distribution of hours as listed on top of second column.

Item	Hours 1953	1954
Sewers	1,030	1,036
Pumping stations:		
No. 1	1,923	1,712
No. 2	441	594
No. 3	381	384
Chlorination	147	115
Channels and pipe gallery	81	81
Comminutors	143	215
Grit removal	1,280	1,779
Clarifiers	6,640	5,278
Digesters	3,971	4,614
Drying beds	2,560	1,815
Building maintenance	3,764	4,681
Ground maintenance	1,345	1,397
Equipment maintenance	1,876	2,899
Adm. and laboratory	4,934	4,931
Total	31,955	31,559
Vacation	1,356	1,436
Sick Leave	342	446

In addition to the work at the treatment plant, the operating staff put in 1,162 hr. in 1953 and 1,698 hr. the following year in outside or off-site work of a maintenance nature for the city.

Salaries

Salaries are set by the Finance Committee of the city's council. Wages constitute 65 to 68 per cent of the total operating cost. Due to the inauguration of the 40 hr. week on Jan. 1, 1954 this budgetary item increased from $62,933.83 to $70,956.00. Another benefit increase for employees was the lowering from 20 yr. to 15 yr. the number of years of service necessary to be eligible for three weeks vacation.

Present annual salary scales are:

Superintendent	$6,938.04
Chemist	3,800.49
Mechanic	4,223.16
Mechanic helper or operator	3,983.16
Utility man	3,863.16

In addition to two weeks annual vacation, 12 days per year sick leave is received and cumulative to 120 days. Surgical and hospitalization insurance is provided and all personnel are covered by social security.

Annual Report of the Ley Creek Sewage Treatment Plant, Onondaga County, N. Y., for the Year 1953 *

By Uhl T. Mann, *Superintendent*

The Ley Creek Sanitary District serves a small section of the city of Syracuse, the village of East Syracuse, several unincorporated communities and several concentrated industrial sites. Resident population of the sanitary district is estimated at 35,000, but the influx of many large industries has resulted in a population equivalent of approximately 100,000.

Originally constructed as a public works project in the period 1935–40, the 4.5 m.g.d. activated sludge plant

* Winner of the Hatfield Award, 1954, Class II for sewage treatment plants serving populations of 10,000 to 100,000.

replaced six small sewage treatment plants. The small volume of flow in Ley Creek requires a high degree of treatment. By 1945, the treatment facilities were badly overloaded, necessitating enlargement to 9 m.g.d. in 1951.

Treatment units consist of screens, grit chambers, pre-aeration tanks, primary settling and aeration units. Separate sludge digestion is followed by sludge drying on either vacuum filters or drying beds. Sludge gas is stored in a 15,000 cu. ft. gas holder and a 40,000 cu. ft. digester. Chlorination of the plant effluent is practiced during the months of May through September.

Present facilities provide pumping capacity for 40 m.g.d., primary treatment for 20 m.g.d. and standard rate activated sludge treatment for 9 m.g.d. Soil conditions at the plant site require the operation of a dewatering system to lower the ground water and eliminate danger of the tanks floating when emptied. Part of this system is used for process water.

TABLE II.—Summary of 1953 Operating Data, Ley Creek (N. Y.) Sewage Treatment Plant

Item	Average
Rainfall (in.)	29.72
Population:	
Connected (estimated)	35,000
Equiv., B.O.D.	135,000
Equiv., susp. sol.	81,500
Sewage flow (m.g.d.)	5.91
Screenings (cu. ft. per m.g.)	4.2
Grit (cu. ft. per m.g.)	6.75
pH:	
Influent	7.36
Settled	7.43
Final effl.	7.59
Settleable solids:	
Influent (ml. per liter)	10.1
Primary effl. (ml. per liter)	1.4
Reduction (%)	87
Suspended solids:	
Influent (p.p.m.)	314
Primary effl. (p.p.m.)	154
Plain aeration effl. (p.p.m.)	71
Activated sludge effl. (p.p.m.)	19
Combined effl. (p.p.m.)	45
Reduction (%)	85.5
B.O.D., 5-day:	
Influent (p.p.m.)	459
Primary effl. (p.p.m.)	310
Plain aeration effl. (p.p.m.)	166
Activated sludge effl. (p.p.m.)	24
Combined effl. (p.p.m.)	112
Reduction (%)	75.5
Activated sludge data:	
Aeration period (hr.)	7.12
Air consumption (cu. ft. per gal. sewage)	1.97
Returned sludge (% by volume)	27.6
Mixed liquor suspended solids (p.p.m.)	1,862
Sludge index	103
D.O., aeration tank (p.p.m.)	2.8
Excess activated sludge (cu. ft. per m.g.)	2,530
Chlorination:	
Days	137
Lb. per day	525
Residual (p.p.m.)	0.59
Raw sludge:	
Pumped per day (cu. ft.)	4,420
pH	6.11
Dry solids (%)	4.6
Volatile solids (%)	72
Digested sludge:	
To drying beds (cu. ft. per day)	3,062
pH	7.46
Dry solids (%)	4.4
Volatile solids (%)	52
Gas production:	
Daily average (cu. ft.)	82,242
Cu. ft. per lb. (dry) volatile solids added	9
Gas analysis:	
CO_2 (%)	33
Power (k.w.h. per day)	3,264
Outlet stream analyses (p.p.m.):	
Upstream ½ mile:	
D.O.	7.6
B.O.D.	14
Susp. sol.	24
Downstream ¼ mile:	
D.O.	4.6
B.O.D.	64
Susp. sol.	56
Stream flow [1] (c.f.s.)	26.5
Treatment costs ($):	
Plant operation	174,517.00
Debt retirement	343,760.00
Per m.g.[2]	81.00
Per capita [2]	1.74

[1] Includes plant effluent.

[2] Does not include debt retirement.

Operation

Construction features of the plant permit operation as two separate units. During 1953, one-half of the plant was operated as a standard rate activated sludge plant while the other half was operated as a plain aeration plant. Each half of the plant received approximately one-half of the flow except when shock loads upset the activated sludge process. At these times the flow was adjusted to permit plain aeration of the larger part of the flow. The combined effluent of the two sections represented a suspended solids reduction of 85.5 per cent and a B.O.D. reduction of 75.5 per cent. Industrial plants produce 60 per cent of the B.O.D. load to the treatment plant.

The population equivalent is 135,000 when based on the B.O.D. load and 81,500 when based on the suspended solids. Daily analyses showed the strongest sewage had a B.O.D. of 800 p.p.m. The aeration units experienced B.O.D. loadings of 57 to 90 lb. per 1,000 cu. ft. of tank capacity. The overload has been calculated at 60 to 100 per cent of design capacity. On many days the primary tanks fail to provide any reduction in the B.O.D. load due to the high percentage of dissolved solids in the sewage.

The activated sludge treatment, however, remained quite constant with little change in solids, air supply, aeration time, sludge wasted or rate of returned sludge.

Reduction in the quantity of screenings (15 per cent) and scum (21 per cent) resulted in better digester operation. Digestion time was reduced, gas production per pound of volatile matter was increased and there was no lost digester capacity due to heavy scum layers. Approximately 1,100,000 cu. ft. of digested sludge was pumped; one-half to drying beds and one-half to lagoons. The vacuum filters were not operated because funds were not provided for the purchase of chemicals. Almost 85 per cent of the digester gas produced was used by the blower gas engines and digester heating system. The present digestion units are overloaded about 17 per cent on the basis of design.

The operation cost increase is attributed entirely to maintenance. As the equipment gets older the need for repairs and replacement increases. The operating staff numbers 27 and is responsible for the treatment plant and sanitary sewers.

The most pressing operation problems are due to industrial wastes and overloaded treatment units. Each year these conditions become more aggravated. It is difficult to control slugs of industrial wastes, although the industries have been most cooperative.

A summary of operating data for 1953 is given in Table II.

SCALE MODEL SEWAGE TREATMENT PLANT

A scale model sewage treatment plant that actually operates has aided the citizens of San Diego, Calif. in understanding this vital municipal service. Designed and constructed under the supervision of Eric V. Quartley, Superintendent, Sewage Treatment Division, the model (Figure 1) represents many hours of diligent work by division personnel.

The model is built to a horizontal scale of approximately 1 in. to 10 ft. while the vertical scale is slightly exaggerated to permit the showing of equipment details. Measuring 5 ft. by 8 ft. in plan the unit is mounted on a sturdy table fitted with casters to facilitate moving. A wood frame glass cover protects the model when on display.

FIGURE 1.—Working model of the San Diego, Calif., sewage treatment plant. Note use of plastic and cut-away sections to reveal working details.

Sewage treatment plant operation is simulated by the model through the utilization of colored water for sewage and sludge. A small centrifugal pump actually pumps the sewage and sludge to the various treatment units. Two waste gas burners utilize butane gas when the model is operating. A 110-v. electric circuit permits street and building lighting and furnishes power for pumps and blower.

Use of plastic walls and cut-away sections permits a ready inspection of the inside details of the buildings and equipment. One of the clarifier-aeration units is empty to permit observation of the rotating sludge scraper mechanism. The second unit is included in the sewage flow pattern, with air being added to the aeration section through the use of an aquarium pump. Several of the digesters have plastic covers and are empty for inspection purposes. The dome of one of the digesters periodically rises and falls to simulate gas storage. Several other similar features complete the working phases of the model.

Constructed primarily for use at a county fair several years ago, the model has been used for display at civic affairs and other public gatherings. It also has been useful as an in-service training medium for new operating personnel. Visitors to the treatment plant get a better grasp of plant operation if they are first given a tour of the model.

Since most of the work on the model was done by volunteers there is no accurate record of the cost. A fair cost estimate given by Superintendent Quarterly is approximately $3,000.00.

TIPS AND QUIPS

Sludge Shovelers

The Select Society of Sanitary Sludge Shovelers, California Branch, formally initiated David B. Lee, Federation Past-President and Executive Secretary Ralph E. Fuhrman at the Federation's Annual Dinner in Atlantic City. Administering the oath was Fred Nelson, Director from California, ably assisted by Alvin Appel. Each candidate was presented with a polished brass shovel symbol of their elevated status.

Reflective Paint

Recent mention was made concerning reflective sheeting for signs (THIS JOURNAL, 1213, Oct., 1955). Now the same manufacturer, Minnesota Mining and Manufacturing Co., St. Paul 6, Minn., has made available a reflective paint specifically designed for application to wood, concrete, and other rough or porous surfaces.

The new reflective liquid is light grey in daylight and blends with concrete or light-colored objects. But at night it reflects a bright silver, about 50 times brighter than white paint. Application is economical, being made by brush or spray-gun, and one coating lasts for approximately a year, depending on weather conditions.

Called Codit reflective liquid (No. 7210), it is available in 4-lb. pails for $5.30 per lb. One pail will reflectorize more than 140 sq. ft. of area.

Typhoid Fever

The provisional rate for typhoid fever reported by the U. S. Public Health Service was 1.4 per 100,000 estimated population for 1954 in the United States. Rates by individual states ranged from a low of .2 cases per 100,000 population to a high of 7.8 cases.

A handful of states in the South and Southwest have case rates above 2 per 100,000. There still is much work to be done in the field of sanitation. An awareness of this need by all of us may serve a useful purpose in our public relations contacts.

Resistant Glass Electrodes

A new type of pH-sensitive glass which will benefit both laboratory and process control users has been announced by Beckman Instruments, Inc., Fullerton, Calif. Electrodes with the new formula glass are good over the entire 0 to 14 pH range at temperatures from 15° C. to 100° C. They are particularly valuable in the range above pH 10 where other electrodes fail to perform satisfactorily. In addition, the new glass electrode offers improved resistance to acids, surface deterioration, aging and alkalis.

Dry Bait Fly Killer

Particle size is important in a dry bait fly killer according to a California Spray-Chemical Corp. announcement. "A study of fly feeding habits revealed that the insects like to pick up particles of a size relative to the size of a football to man. They can't eat a particle of this size, any more than a man could swallow a football. A single particle, therefore, may serve as a final meal for a number of flies."

Ortho Fly Killer Dry Bait is a new product introduced by Calspray for killing both resistant and non-resistant house flies. It is reported that in addition to the particle size, the new bait owes its effectiveness to the perfection of a formulation containing an "attractant" more effective than sugar-based formulas, and one that is unaffected by moisture.

Although less toxic than many organic chemicals in common use, the usual precautions recommended for all pesticides should be observed.

Greenhouse Sludge Drying

The 1953 operation report of the Hamburg, N. Y. sewage treatment plant (population 6,000) presented the following sludge drying times for the use of glass-covered sludge drying beds:

Month	Drying Time (Days) Max.	Av.	Min.
Jan.	35	22	19
Feb.	30	20	18
Mar.	32	22	20
April	30	15	12
May	25	14	12
June	25	17	14
July	20	18	10
Aug.	15	13	8
Sept.	18	15	12
Oct.	25	20	15
Nov.	30	22	20
Dec.	35	39	20

Two glass-covered sludge beds, 60 ft. by 65 ft. and 59 ft. by 124 ft., are utilized. Total bed area is 21,000 sq. ft. and sand depth is 4 to 6 in. Approximately 7,500 cu. ft. of wet sludge is applied each month with the depth of the dose varying from 4 to 6 in. The Imhoff tank digested sludge is not conditioned with chemicals. Sludge pH averages 7.4.

Economical Air-Dried Sludge

H. B. Holcomb, chief operator of the Cortland, N. Y. sewage treatment plant, reports * that the demand by local farmers for dried sludge has resulted in the abandonment of the vacuum filters. The air-dried sludge is now obtained from an enlarged drying area and from a three-section lagoon. The sludge is used on oats, corn and grass. There is no charge for the sludge removed from the lagoons. The funds used previously for conditioning chemicals for sludge filtration have now provided a 3,500 ft. asphalt drive to the treatment plant. The treatment facilities serve a population of 19,000.

* Extracted from 1953 operating report.

Gamma-Ray Sterilization

Noted recently was the statement that "after six months of research sanitary engineers have demonstrated that water-borne sewage can be sterilized by gamma-radiation without activating or leaving residual radiation in the treated liquids."

Gamma-rays have been used effectively by the U. S. Army and Atomic Energy Commission in the radiation sterilization of certain foods. It is not improbable that some manifestation of this atomic age will be a common feature in the sewage treatment plants of tomorrow.

Program Titles

"Who Invented Filters and How Did They Grow?", "The Wild Life Found in Filters," and "What Are Those Bugs Doing on Those Rocks?" are a few of the titles of the presentations made on the panel discussion "Trickling Filters, A to Z" presented at the 1955 Iowa Association Meeting. Interesting titles for good presentations such as these are needed both at local and national meetings. Many good interesting papers go unread or receive only passing notice because of a title that dulls the reader's appetite. We aren't recommending catch titles to compete with the popular fiction magazines, but we do think that the 1956 program chairmen should consider incorporating a little reader appeal in the program.

Reviews and Abstracts*

Extractive Production of Vitamin B_{12} from Milorganite. By W. F. Stevens, B. Wolnak and R. E. Zinn. *Chem. Eng. Prog.*, 51, 4, 163 (Apr. 1955).

This article describes the process that has been developed to extract Vitamin B_{12}, with special emphasis on the pilot plant tests by which commercial operation of the process was proved feasible.

In the pilot plant the Milorganite was prewet by concentrated extract solution in an agitated tank. From this tank the resultant slurry overflowed to the slowly moving surface of a horizontal filter, where the solid was counter-currently washed with progressively weaker liquors until practically all the soluble solids had been recovered. The remaining wet solid was discharged from the filter and redried, producing a product unchanged in fertilizer value.

The concentrated extract liquor is drawn off continuously, evaporated to a thick syrup, and spray-dried to produce Vitamin B_{12} suitable for animal feed enrichment. Flow diagrams and tables indicate the patented operating procedure. Pilot plant tests indicate an average B_{12} recovery of 18.2 mg. per lb. of concentrate. A plant to handle 8 tons of Milorganite per hour is envisioned. Langdon Pearse

The Treatment and Disposal of Sewage Sludge, a Report of an Informal Working Party. Ministry of Housing and Local Government, London. H. M. Stat. Off., London, Eng. 64 pp. (1954).

This is a comprehensive report by a committee of British engineers and chemists on sewage sludge practices in Great Britain, with comment on U. S. practice.

The main topics are: extent of problem (4 pp.); sludge treatment (13 pp.); dehydration (15 pp.); final disposal (11 pp.); production, use and sale of by-products (9 pp.); costs (1 p.); discussion of problem (5 pp.); and conclusions and recommendations (4 pp.) The committee recommends that the larger sewage disposal authorities be encouraged to continue or to initiate research into the practical aspects of new processes of sludge treatment.

The report is worth reading and may be obtained for $0.65 from the British Information Services, 30 Rockefeller Plaza, New York 20, N. Y. Langdon Pearse

Recent Research Work at the Northern Outfall Works of the London County Council. By A. Bruce, G. S. Clements, and R. J. Stephenson. *Jour. and Proc. Inst. Sew. Purif.* (Brit.), Part IV, 238 (1953).

The authors discuss the following investigations, carried on over the last four years:

Sludge Freezing—Laboratory experiment on frozen sludge would indicate that sludges are amenable to treatment on some paper-making machines.

Availability of Nitrogen—Results definitely indicate that the nitrogen in activated sludge compares favorably with that in dried blood as regards availability, and it is more readily available than the nitrogen in other sludges.

Digestion of Activated Sludge—A considerable loss of nitrogen in the sludge solids was noted when concentrated activated sludge was digested 12 days at 85° and 100° F.

Sludge Concentration—A picket-fence thickener tank used on primary sludge produced an increase in total solids in the lower 6 ft. of sludge thickened.

Concentration of activated sludge in a settling tank indicated that sludge with an initial solids content of 0.7 per cent could

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

be continuously concentrated for periods up to 8 days, producing an average solids content of 3 per cent.

Chlorination—Experiments on chlorination of the primary effluent from the Northern Outfall Works in the summers of 1951 and 1952, on the basis of satisfying one-third of the 15 min. chlorine demand of 140 m.g.d. (Imp.), indicated that the effect of chlorination on the river was insufficient to justify the expenditure.

Diffuser Tile Cleaning—Results of three years of studies indicated the use of chemicals in cleaning diffusers was helpful.

Flow Distribution—At the Northern Outfall Works the distribution of flow and strength of the sewage during 24 hr. was similar to that found 20 yr. before, but the average hourly flow had increased from 7.1 to 8.3 m.g.d. (Imp.) The peak flow rose to 300 m.g.d. (Imp.) by midafternoon, as compared with 100 m.g.d. (Imp.) at 6 A.M. About 14 per cent of the total pollution load occurred for an hour at 4 P.M., as compared with 3 to 4 per cent at 6 A.M. The total B.O.D. ranged from 3,520 to 11,440 lb. per hr. and the suspended solids from 7,260 to 30,140 lb. per hr.

LANGDON PEARSE

The Numbers of Pathogenic Bacilli in Faeces in Intestinal Diseases. By SCOTT THOMSON. *Jour. of Hyg.*, 53, 2, 217 (1955).

Gastro-enteritis caused by certain varieties of *B. coli* is a highly infectious disease among babies. Large numbers of pathogenic varieties of *B. coli* were found in the faeces in such cases, but very large numbers of the pathogenic *B. coli* were also found in dysentery, salmonella food-poisoning and in some cases of paratyphoid fever.

H. HEUKELEKIAN

Potential for Steel Mill Waste Disposal. Electrolytic Treatment of Waste Sulfite Pickle Liquor Using Anion Exchange Membranes. By C. HORNER, A. G. WINGER, G. W. BODAMER AND R. KUNIN. *Ind. Eng. Chem.*, 47, 1121 (1955).

Reports on a laboratory scale experimental unit are given. A comparison of the cost of treating waste pickle liquor with lime and ion exchange membranes is given. Present cost estimates indicate that the process should be economical because sulfuric acid in a usable concentration and iron can be recovered thereby reducing the operating cost.

R. S. INGOLS

Identification of Petroleum Refinery Wastes in Surface Waters. By A. A. ROSEN AND F. M. MIDDLETON. *Anal. Chem.*, 27, 790 (1955).

The aliphatic and aromatic hydrocarbon fractions separated from the wastes of five refineries showed infrared spectral patterns which were similar and sufficiently characteristic to suggest their use for identification. The organic materials in three samples of surface waters containing varying amounts of refinery wastes were concentrated with activated carbon. Hydrocarbon fractions separated by chemical procedures were found by their infrared spectral patterns to be similar to or derived from the refinery wastes. This method provides chemical evidence of the presence of low concentrations of hydrocarbons in petroleum refinery wastes independent of subjective methods, yet with good sensitivity.

R. S. INGOLS

Water Analysis. By S. K. LOVE AND L. L. THATCHER. *Anal. Chem.*, 27, 680 (1955).

A review of methods of water and sewage analysis covering articles appearing over a two year period with 248 literature citations.

R. S. INGOLS

The Isolation and Characteristics of an Organism Oxidizing Thiocyanate. By F. C. HAPPOLD, K. I. JOHNSTONE, H. J. ROGERS AND JEAN B. YOUATT. *Jour. of General Microbiology*, 10, 1–3, 261 (1954).

The isolation, morphology, cultural characteristics and growth requirements are described for an autotroph that oxidizes thiocyanate. It is suggested that the organism be assigned to the genus Thiobacillus.

H. HEUKELEKIAN

Dosing Rates and the Efficiency of Percolating Filters. By T. G. TOMLINSON AND H. HALL. *Surveyor*, 114, 145 (1955).

Experiments were performed with two pairs of alternating double filters to determine the effects of the speed of the rotary distributors on the results obtained. On the control pair of filters the dis-

tributors were driven by the reaction force of the sewage issuing from the arms. The time per revolution varied from about 1 to 5 min. The distributors of the other pair were electrically driven at predetermined speeds.

The purification results obtained with the fixed-speed distributors may be summarized as follows:

Revolution Time (min.)	Effluent B.O.D. (% of control values)	Effluent NO_2+NO_3 (% of control values)
8	105	130
15	70	258
30	66	293
42	116	224
55	82	264

The authors also observed that with the lower rate of rotation, the condition of the filters was improved; there was less ponding, and the film was thinner and less anaerobic. M. C. RAND

Report of the Water Pollution Research Board for the Year 1954. Dept. Scientific and Ind. Research. H. M. Stat. Off., London, S.E. 1, Eng. 65 pp. Price, $0.75 (1955).

The 1954 annual report of the British Water Pollution Research Board includes an account of the new laboratory in Stevenage. The field investigations and experimental work in connection with the survey of the Thames estuary have been completed. Investigations on the effect of pollution on fish in the Colne river are described.

Studies on the effect of detergents on sewage treatment have been inconclusive. Detergents may reduce the rate of oxygen absorption from the atmosphere, thus delaying the rate of recovery of a polluted stream. In addition detergents are toxic to fish.

The work on the treatment of water, sewage, and industrial wastes included studies of large and small percolating filters. Successful treatment of cyanides by the organism *Actinomycete* on trickling filters and the anaerobic digestion of partially neutralized black liquor from kiering cotton were discussed.

Copies of the report also can be obtained from the British Information Services, 30 Rockefeller Plaza, New York 20, N. Y.

D. P. S.

BOOKS, REPORTS, AND PAMPHLETS

Organic Chemistry Simplified. Chemical Publishing Co., Inc., 212 Fifth Ave., New York 10, N. Y. 620 pp. Price, $12.00 (1955).

Estimated Water and Sewerage Construction Cost of Projects Remaining in the Advance Planning of Nonfederal Public Works Programs. U. S. Dept. of Commerce, Business and Defense Services Adm., Washington 25, D. C. 34 pp. Price, $0.20 (1955).

A Better Air Power System. Publ. Form 213-A. Ingersol-Rand Co., 11 Broadway, New York 4, N. Y. (1955).

Pipe Friction Manual. Hydraulic Institute, 122 East 42nd St., New York 17, N. Y. 87 pp. Price, $1.75 (1954).

An excellent manual presenting mathematical calculations and example problems on pipe hydraulics. Included are valuable tables and full page charts on resistance coefficients and friction losses.

Tapping Manual for Prestressed Concrete Pipe. Price Brothers Co., P. O. Box 825, Dayton 1, Ohio (1955).

Silent Service Is Not Enough! American Water Works Assn., 521 Fifth Ave., New York 17, N. Y. 152 pp. Price, $1.50 (1955).

A collection of excellent articles of public relations techniques and ideas for water utilities as reprinted from the Dec., 1954 *Journal* AWWA.

85% Magnesia Insulation Manual. The Magnesia Insulation Manufacturers Assn., 1317 F St., N.W., Washington 4, D. C.

This revised second edition covers the applications, and chemical and physical properties of 85 per cent magnesia insulation.

Water Pollution Abatement Manual. Manufacturing Chemists Assn., Inc., 1625 Eye St., N.W., Washington 6, D. C. 12 pp. Price, $0.25 (1955).

Manual W-4 discusses the permissible concentrations, sources and removal of oils and tars.

Book Reviews

Proceedings of the Ninth Industrial Waste Conference. *Eng. Bull.*, 39, No. 2 (Extension Series No. 87). Purdue Univ., Lafayette, Ind. 591 pp. Price, $2.50 (March, 1955).

The papers included in the "Proceedings" are those presented at the Ninth Conference, held May 10–12, 1954, as follows:

"Applications of Ion Exchange to Plating Plant Problems," by R. T. Keating, R. Drovin and V. J. Calise.

"Factors in the Development of an Industrial Waste Ordinance," by W. G. Hamlin.

"Industrial Waste Treatment at the Ternstedt Division—Flint Plant," by John S. Delos.

"Disposal of Organic Chemical Wastes to Underground Formations," by J. Adinoff.

"Industrial Waste Problems at Northeast in Philadelphia," by Ralph A. Hoot.

A Symposium, "Air Diffusion in the Treatment of Industrial Wastes by the Activated Sludge Process": "The Problem," by Christian L. Siebert. "Biological Oxidation Aerators," by R. Rupert Kountz and John C. Villforth. "Air Diffusion for Activated Sludge," by Douglas E. Drier. "Air Diffusion in the Treatment of Industrial Wastes," by G. E. Hauer.

"Uses of Lime in Treating Oil Wastes," by Thomas F. Brannan, James E. Etzel and Don E. Bloodgood.

"Biochemical Oxidation of Dairy Wastes," by Sam R. Hoover, Lenore Jasewicz and Nandor Porges.

"Wastes Treatment—Fairless Works," by G. A. Howell.

"Effluent Improvement Program at Humble's Baytown Refinery," by S. O. Brady.

"The Relationship Between Biochemical Oxygen Demand in a Treated Industrial Effluent," by Summer Kaufman.

"Removal of Radioactivity by Ion-Exchange," by H. Gladys Swope.

"Some Geological Factors in Underground Waste Disposal," by Norman F. Billings.

"Limitations in the Use of Sanitary Landfill as a Method of Solid Trash Disposal," by Wilbur C. Webb.

"Treatment of a Strong Industrial Waste Containing Carbohydrates and Chromium," by George A. Rhame.

"Recent Developments in Textile Waste Treatment," by Nelson Nemerow and Hobart Souther.

"Stream Pollution Abated Jointly by the City of Cedar Rapids and Its Industries," by C. D. Mullinex.

"Production of Vitamin B-12 From Milorganite," by Ray D. Leary.

"Disposal of Phenolic Waste to Underground Formations," by A. C. Lansing and P. S. Hewett.

"Treatment of Waste from Small Slaughterhouses," by R. Rupert Kountz.

"The Disposal of Sludge from a Lime-Soda Softening Plant as Industrial Waste," by George D. Russell and George S. Russell.

"Some Revised Concepts Concerning Biological Treatment," by Clair N. Sawyer, John D. Frame and John P. Wold.

"New Developments in Dairy Waste Treatment," by Dr. K. L. Schulze.

"Clarification of Oil Contaminated Waters," by Jack E. Shideler, Jr.

"Citrus Waste Disposal Practices and Research," by J. W. Wakefield, Ben. F. O'Neal and Mrs. Foymae S. Kelso.

"Chemical Wastes," by D. M. Vail.

"Physico-Chemical Characteristics of Liming Materials as Related to Neutralization of Mineral Acids," by L. John Minnick and C. Presgrave.

"Diatoms as an Indication of River Change," by Ruth Patrick.

"Further Operating Experiences on Biological Purification of Formaldehyde Wastes," by B. W. Dickerson, C. J. Campbell and M. Stankard.

"Industrial Waste Treatment in Ontario," by A. V. De Laporte.

"Plating Wastes—A Review of Research," by D. Gardner Foulke and Raymond F. Ledford.

"Disposal of Waste Pickle Liquor by Controlled Oxidation and Continuous Lime Treatment," by Lorenz W. Heise and Milton Johnson.

"Vacuum Evaporation and De-ionization for the Recovering of Plating Material," by Anthony J. D'Orazio.

"Plating Waste Treatment and Water Reclamation for the Maytag Company," by T. C. Hoppe and W. L. Gasper.

"The Electrolytic Treatment of Waste Sulfate Pickle Liquor Using Permselective Membranes," by Collins Horner, Alvin Winger, George Bodamer and Robert Kunin.

"Modern Waste Disposal and Recovery in a Petroleum Refinery," by A. D. McRae.

"Acclimation of Microorganisms for the Oxidation of Pure Organic Chemicals," by E. J. Mills, Jr. and Vernon T. Stack, Jr.

"Color Removal from Kraft Mill Effluents," by W. A. Moggio.

"Soluble Oil and Industrial Cleaning Waste Treatment," by George L. Sukes.

"Chlorine Gas Feeders Applicable in Industrial Waste Treatment and Principles of Operation," by R. W. Pearce.

"Water Quality Criteria," by W. W. Towne and John W. Wiseman.

"The Aerobic Biological Treatment of Organic Wastes," by W. Wesley Eckenfelder, Jr. and Donald J. O'Connor.

"Designs for Control and Treatment of Wastes at West Virginia Pulp and Paper Company," by Harold E. Miller and James M. Kniskern.

"The Design and Operation of the Waste Treatment Works in Buick's Jet Engine Assembly Plant at Willow Springs, Illinois," by R. J. Brink.

"Treatment of Waste from Dye Manufacture at the Ciba States Ltd. Plant at Toms River, New Jersey," by John J. Baffa.

A cumulative index of the first nine "Proceedings" is included. D. P. S.

The Municipal Year Book, 1955. Clarence E. Ridley and Orin F. Nolting, editors. International City Managers Assn., 1313 E. 60th St., Chicago 37, Ill. 588 pp. Price, $10.00 (1955).

The 1955 (22nd) edition of this municipal administrator's standard reference contains new sections on the role of city government in providing cultural activities, problems and data on annexations and metropolitan area developments, and municipal nonproperty taxes adopted by cities over 5,000 population. New planning statistics are included for cities over 10,000 population and new data is provided on fire and police departments.

In addition, the regular sections have been brought up-to-date, while significant municipal developments during the previous year are reviewed. Summary articles precede each major table in the book.

D. P. S.

Manual on Industrial Water. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. 420 pp.

Prepared by ASTM Committee D-19 on Industrial Water, this 1954 printing has been brought up to date by the inclusion of new and revised methods issued in 1953 and 1954. However, there have been no changes in the chapter headings as originally published in 1953. The text is based on the ASTM standards for industrial water use.

D. P. S.

Water Supply Engineering. Fifth Edition. By Harold E. Babbitt and James J. Doland. McGraw-Hill Book Co., Inc., New York, N. Y. 806 pp. Price, $8.50 (1955).

The new fifth edition of this well-known text and reference work incorporates information on the latest accepted practices in the field of waterworks. It covers not only public and private water supplies as in previous editions, but also industrial water supplies. Particular emphasis is placed on the various factors needed for a complete waterworks design, including maintenance and operation. H. P. O.

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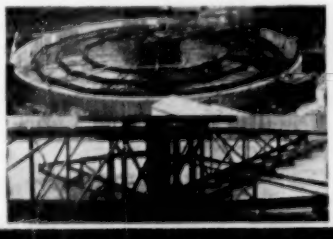

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Proceedings of Member Associations

MARYLAND-DELAWARE WATER AND SEWAGE ASSOCIATION

The 28th Annual Conference of the Maryland-Delaware Water and Sewage Association was again held at the Commander Hotel, Ocean City, Md., on May 26–27, 1955.

The technical sessions featured the following papers of interest to sewage works personnel:

"Financing of Sewerage Systems for Small Towns," by Kenneth A. McCord, Whitman, Requardt and Associates, Baltimore, Md.

"Maintenance and Operation of Sanitary Sewers and Sewage Pumping Stations," by Louis Hauptman, Pumping Division, Baltimore County Metropolitan District, Towson, Md.

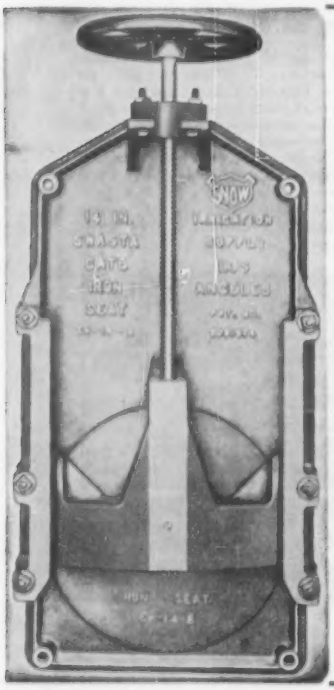
An interesting program of entertainment was enjoyed by those in attendance.

At the Business Meeting a constitutional amendment was presented providing for the exemption from dues for all members of 10 yr. standing upon reaching age 65. Officers elected to serve for 1955–56 were:

President: T. F. O'Connor, Washington, D. C.
1st Vice-President: John Krasauskas, Washington, D. C.
2nd Vice-President: Robert H. Hartman, Frederick, Md.
Secretary-Treasurer: W. M. Bingley, Baltimore, Md.

W. McLean Bingley,
Secretary-Treasurer

(*Continued on page 516a*)



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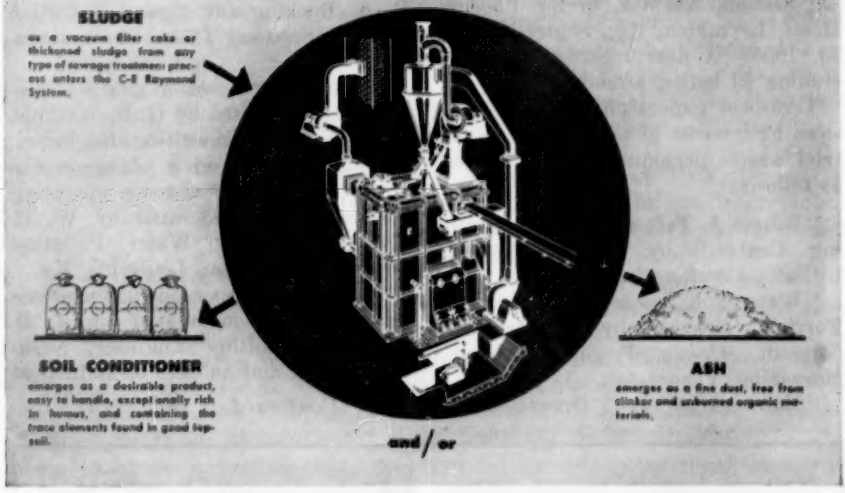
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KENTUCKY-TENNESSEE INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The 1955 Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association was held jointly with the Kentucky-Tennessee Section, AWWA, in the Phoenix Hotel, Lexington, Ky., September 12–14, 1955. A near record of 274, including 43 ladies, attended.

Technical papers and panel discussions of interest to sewage and industrial wastes personnel were presented as follows:

"Robert A. Taft Sanitary Engineering Center," by F. W. Kittrell, USPHS, Cincinnati, Ohio.

"Water and Sewerage Problems in Foreign Areas," by Howard D. Schmidt, Creole Petroleum Corp., Maracaibo, Venezuela.

"Maintenance and Operation of Pumping Equipment," by Charles E. Coleman, Assistant Chief Engineer, Pump Dept., DeLaval Steam Turbine Co., Trenton, N. J.

"Lexington's Proposed Incinerator," by Herbert D. Fritz, City Manager, Lexington, Ky.

"Stream Analysis by Statistical Methods," by M. A. Churchill and R. A. Buckingham, Stream Pollution Control Section, TVA, Chattanooga, Tenn.

A panel discussion on sludge digestion was moderated by G. R. Watkins, J. S. Watkins Consulting Engineers, Lexington, Ky., and a sewage works operators' forum featuring operating personnel was moderated by W. C. Martin, Kentucky Water Pollution Control Commission, Louisville, Ky.

Other panel discussions included one on infiltration moderated by J. S. Parker, Consulting Engineer, Nashville, Tenn., and another on industrial

(*Continued on page 517a*)

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waste treatment moderated by Lyman Cox, E. I. du Pont de Nemours & Co., Old Hickory, Tenn.

Two films featured were "Flexible Sewer Cleaning Equipment in Action" and "Clay Sewer Pipe."

The following officers were elected to serve during 1955–6:

Chairman: Charles M. Davidson, Chattanooga, Tenn.
Vice-Chairman: Louis F. Birkel Louisville, Ky.
FSIWA Director: Grant S. Bell, Louisville, Ky.
Secretary-Treasurer: S. Leary Jones, Nashville, Tenn.

S. LEARY JONES,
Secretary-Treasurer

CANADIAN INSTITUTE ON SEWAGE AND SANITATION

The 22nd Annual Convention of the Canadian Institute on Sewage and Sanitation was held in the McIntyre Arena, Schumacher, Ont., on September 28–30, 1955. An excellent meeting and attendance marked this meeting in northern Canada.

The technical meeting was composed of symposiums on water conservation and pollution control, New Developments in waste treatment, supervision over small sewage treatment works, and planning for new townsites and subdivisions. Papers presented were as follows:

"Conservation under the Prairie Farm Rehabilitation Administration," by E. L. Gray, Superintendent of Water Development, Prairie Farm Rehabilitation Administration, Regina, Sask.

"Standards for Stream Pollution," by J. R. Menzies, Chief Engineer, Department of National Health and Welfare, Ottawa, Ont.

"The Economics of Gold Mining in Northern Ontario and the Disposal of Mining Wastes," by Robert E. Findlay, Manager, Aunor Gold Mines Limited, Timmins, Ont.

"Municipal Sewage," by W. B. and D. B. Redfern, Consulting Engineers, Toronto, Ont.

"Industrial Wastes," by Morris M. Cohn, Editor, *Wastes Engineering*, New York, N. Y.

"Disposal of Wastes Associated with Oil and Gas Production," by Cooper Drabble, Divisional Petroleum Engineer, Imperial Oil Limited.

"Civilian Plants," by Loren Nielsen, Chicago Pump Co., Chicago, Ill.

"Military Plants," by Major F. E. Barr, Director of Works, Department of National Defense, Ottawa, Ont.

"Design and Government of New Townsites," by A. E. K. Bunnell and A. E. Gomme, Ontario Department of Planning and Development, Toronto, Ont.

"Water and Sewer Services," by R. V. Anderson, Consulting Engineer, Toronto, Ont.

"Municipal Organization, Job Classification and Employer—Employee Relations," J. R. Stuart, City Personnel Manager, Winnipeg, Man.

A guided discussion, chairmaned by J. H. Irvine, Ottawa, featured factors in the location and operation of sewage treatment works.

Inspection trips were made through the local industries—gold mining, lumbering and paper manufacturing. E. Sherman Chase represented the Federation and presented an after-dinner talk on his recent travels in Europe.

Officers elected to serve during 1955–6 were:

President: C. G. R. Armstrong, Windsor, Ont.
Vice-President: L. B. Allan, Toronto, Ont.
FSIWA Director: C. S. Anderson, South Porcupine, Ont.
Secretary-Treasurer: A. E. Berry, Toronto, Ont.

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(*Continued on page 518a*)

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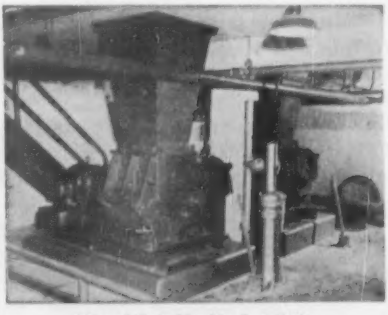

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SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 1955 Annual Meeting of the South Dakota Water and Sewage Works Conference was held in Mobridge, S. Dak., September 21–23, 1955. Registration for the meeting totaled 89.

Papers presented of interest to sewage works personnel included the following:

"The Saline Water Conversion Program," by E. H. Sieveka, Chemical Engineer, U. S. Department of Interior.

"Environmental Sanitation in India," by Professor George L. Jacobsen, School of Mines and Technology, Rapid City.

"The South Dakota Water Resources Commission," by A. E. Munck, Commission Chairman, Pierre.

"Sewage Plant Fire and Sewer Explosions at Aberdeen," by Siger Bies, Superintendent, Sewage Treatment Plant, Aberdeen.

An operators' discussion period was a featured item of the Sewage Works Section. Inspection trips were made to the Mobridge water treatment plant and to the facilities of the Montana Dakota Utilities Co.

Several awards to meritorious water and sewage works operators were made at the Annual Banquet.

At the business luncheon the recently initiated water and sewage plant operators' voluntary ceritification program was discussed. A written examination was held for qualified operators.

The following officers were elected to serve during 1955–6:

President: Charles Clark, Mitchell.
Vice-President: Leo Hericks, Hoven.
Secretary-Treasurer: Charles E. Carl, Pierre.

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Equipment and Supply Lines

Sewage Disposal Screen—New literature release illustrates installation, advantages, and operation of "North" sewage disposal screens.—Green Bay Foundry and Machine Works, Green Bay, Wis.

Power Stirrer—A heavy-duty laboratory stirrer featuring a hollow spindle for dynamic balance is presented in Bulletin 530—Eberbach Corp., Ann Arbor, Mich.

Close-Couple Pumps—Bulletin Form 7093-E covers the entire line of close-coupled pumps in a wide range of capacities and horsepower ratings.—Ingersoll-Rand, Cameron Pump Division, 11 Broadway, New York 4, N. Y.

Electric Motors—A new 28-page Catalog GEC-1026 presents complete buying information on standard a-c fractional and integral horsepower electric motors in most general use—General Electric Co., Schenectady 5, N. Y.

Air Diffuser—Colaflex, a new flexible fabric diffuser element described in Bulletin 6530-B is circular in shape and features easy cleaning by collapsing the element—Infilco Inc., 921 South Campbell Ave., Tucson, Ariz.

Screen and Comminutor—A combination screen and comminutor for large flows, the "Rotagrator" is a bar screen that holds solids upstream until the comminuting section reduces them to a size permitting passage through the screen.—Infilco Inc., 921 South Campbell Ave., Tucson, Ariz.

Controlled Volume Pumps—Bulletin H20-1 describes controlled volume pumps for accurate chemical feed.—Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Pipe Cutter—An improved light weight asbestos-cement pipe cutter is now available.—Spring Load Manufacturing Corp., 317 Vance Bldg., Seattle, Wash.

Odor Control—A deodorizing agent reported to be especially helpful in masking and controlling odors of putrefaction resulting from protein decomposition has recently been announced.—Fritzsche Brothers, Inc., 76 Ninth Ave., New York 11, N. Y.

Positioning Relay—A positioning relay kit for improving the operation of air-operated control valves is described in Bulletin P99-5.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

Incinerator Equipment—Buckets and grapples for municipal incinerator service are described in the 24-page Bulletin 2350-R.—Blaw-Knox Co., Farmers Bank Building, Pittsburgh, Pa.

Protective Coatings—A 19-page report on "Comparative Properties of Protective Coatings" contains information on 14 types of coatings. Physical and chemical data, and charts aid in the selection of appropriate materials.—Atlas Mineral Products Co., Mertztown, Pa.

Waste Treatment Equipment—Water, waste and sewage treatment equipment is described in the new 24-page illustrated Bulletin G-50.—Walker Process Equipment Inc., P. O. Box 266, Aurora, Ill.

Solenoid Valves—Electrically controlled magnetic solenoid valves are illustrated and described in a comprehensive catalog.—Magnatrol Valve Corp., Hawthorne, N. J.

Steel Belt Conveyors—A 48-page, hard cover book presents extensive engineering and application information on steel belt conveyors for material handling.—Sandvik Steel Belt Conveyors, 1702 Nevins Road, Fair Lawn, N. J.

Electric Motor Controls—Redesigned high-voltage motor controls, reported to save 50 per cent in floor

(*Continued on page 522a*)

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space over previous models, are described in Bulletin GEA-6331. A number of safety features are also incorporated in these Limitamp controls. —General Electric Co., Schenectady 5, N. Y.

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Pilot Pressure Filter—A fully enclosed 3-leaf pressure filter with a net filtering area of 1 sq. ft. is available for pilot plant research and production filter selection.—American Plant Equipment Co., 701 Spring St., Elizabeth 4, N. J.

Ball Valve—For water and steam service a precision ball valve, utilizing four "O" rings as a seal, is described in a recently issued illustrated folder.—Carpenter Valve Corp., 6723 Denison Ave., Cleveland 2, Ohio.

Stainless Steel Valves—Catalog No. 55 furnishes technical data for stainless steel valve design, selection, maintenance and repair.—Cooper Alloy Corp., Hillside, N. J.

Sludge Digestion System—A 16-page, two-color bulletin describes the development, equipment, operation, design loadings and typical applications of the "Densludge" digestion system. —Dorr-Oliver Inc., Stamford, Conn.

Submersible Utility Pump—A small submersible utility pump with a capacity of 55 g.p.m. at 20 ft. head is available for building sumps and similar locations.—Kenco, Inc., 1127 N. Ridge Road, Lorain, Ohio.

Plug Valve Lube Manual—Lube Manual No. 3 provides information on lubricants for plug valves used on various services. Included is descriptive material on plug valve construction.—Valve Div., ACF Industries, Inc., 1501 E. Ferry Ave., Detroit 11, Mich.

Lab Heaters—A recently announced series of versatile heaters for laboratory use should replace the standard hot plate where fast response to control settings is desired. A beveled "flip-over" ceramic top safely accommodates either large or small flasks.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

Midget Thermostats—A ¼-in. diameter, 2½-in. long thermostat with a temperature range of − 50° F. is available for 115 v. A.C. at 1 amp.—Fenwal Inc., Ashland, Mass.

Pneumatic Transmitter—Technical Bulletin 285–L2A supplements previous Bulletin 285–L2 describing a newly-developed pneumatic transmitter for liquid level, pressure and flow measurements. — Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

Chlorinator—A heavy duty compact hypochlorinator for private water and sewage use is described in Bulletin 1201–2.—Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I.

Oil Seals—A 28-page manual covers the selection, application and installation of asbestos — compound "Clipper" oil seals. Data is tabulated and important points illustrated.—Johns-Manville, 22 E. 40th St., New York 16, N. Y.

Teflon Packings and Gaskets—Complete descriptions of Teflon packings, gaskets and similar products, respectively, are given in Bulletins CP552, CP553 and CP554.—Chemical & Power Products, Inc., 11 Broadway, New York 4, N. Y.

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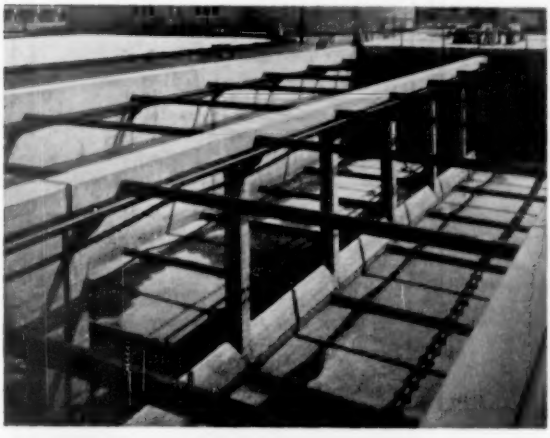

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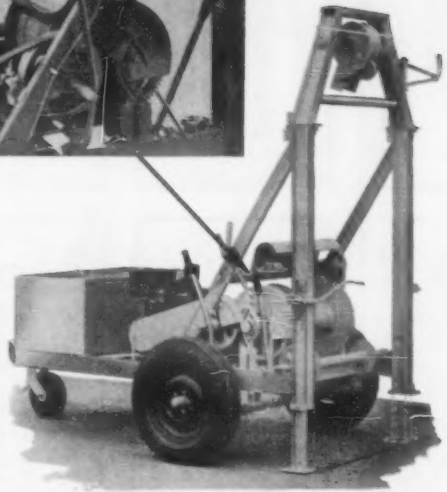

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	Page
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Cast Iron Pipe Research Association	498a, 499a
Chapman Valve Manufacturing Company	504a
Chicago Pump Company	491a
Combustion Engineering, Incorporated (Raymond Division)	515a
Dorr-Oliver, Incorporated	512a
Flexible Incorporated	532a
General Chemical Division (Allied Chemical & Dye Corporation)	501a
Gruendler Crusher & Pulverizer Company	518a
Isertol Company, Incorporated	507a
Lalico Incorporated	497a
Jeffrey Manufacturing Company	535a
Johns-Manville Corporation	505a
Lakeside Engineering Corporation	514a
Link-Belt Company	503a
Morse Boulger Destructor Company	533a
Nichols Engineering & Research Corporation	519a
Pacific Flush Tank Company	515a
Portland Cement Association	509a
Rockwell Manufacturing Company (Nordstrom Valve Division)	506a
Simplex Valve and Meter Company	498a
Smith & Loveless, Incorporated	503a
Snow Gates & Valves	514a
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Walker Process Equipment Incorporated	513a
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